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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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ATTITUDES TOWARD FISHING AND FISHERIES MANAGEMENT OF USERS IN DESOLATION WILDERNESS, CALIFORNIA [1]

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Users of Desolation Wilderness sampled from a list of wilderness area permittees were surveyed to determine their attitudes towards the fish resources and the fisheries management policies in the Desolation Wilderness. Although only a small proportion came to the Area primarily to fish, 40% of the respondents brought fishing gear. The present fisheries management policies were supported by 68% of those surveyed; only 13% of the respondents held negative attitudes about these programs.

INTRODUCTION

Desolation Wilderness is located astride the Sierra Nevada crest in eastern El Dorado County, California. It is approximately 145 km (90 miles) east of Sacramento and immediately west of Lake Tahoe. The El Dorado National Forest administers the 25,686-ha (63,469-acre) area while the California Department of Fish and Game is responsible for its fish and wildlife resources. Fisheries management consists principally of maintenance stocking of fingerling trout by aircraft.

Much of the wilderness is remote, but some areas near Lake Tahoe and Highway 50 are so readily accessible that many people visit the Area on a day-use basis. During the past few years, Desolation Wilderness has experienced a dramatic increase in the number of visitors. In 1965, only 3,600 persons used the Area (House Document 1968). By 1973, the number had risen to an estimated 40,000 visitors (El Dorado National Forest, unpublished data). Ecological damage, mainly in camping area near lakes and streams, in the form of soil compaction, water pollution, and vegetation destruction, has accompanied this rapid increase in use. In 1971, the U.S. Forest Service initiated a permit system in the Area with the idea of controlling use to alleviate pressure on the stressed areas. However, compliance with the permit system has been approximately 50% (El Dorado National Forest, unpublished data), and it did not appear the present system would be effective in achieving the desired results. Additional measures to reduce use were sought.

In discussions held between representatives of the U.S. Forest Service and California Department of Fish and Game, representatives of the Forest Service suggested that if fishing were a primary motivating factor

[1] Accepted for publication September 1975. This work was performed as part of Dingell-Johnson California Project F-6-C, "Fish Management Coordination", supported by Federal Aid to Fish Restoration funds.

underlying the use of the Desolation Wilderness, then discontinuing fish planting to allow the fisheries to deteriorate in the critical use areas might reduce pressure. However, if fishing were not the primary motivation for using Desolation Wilderness, discontinuing fish planting would only serve to penalize those users who wished to make fishing a part of their wilderness experience.

In conjunction with the above, the acceptance of fisheries management practices by wilderness area users was considered. Some felt that any external management of the fisheries resource violates the essence of a true wilderness, and consequently reduces the quality of a "wilderness experience" for users of the Area. Others felt that the present level of fisheries management did not impair the wilderness values, but rather aided in making the outing more enjoyable for users interested in fishing. Since specific information was needed to determine which of the preceding considerations was more valid, a study was undertaken to assess the attitudes of wilderness area users toward fishing and fisheries management, and their evaluation of their wilderness outing.

METHODS

A survey instrument was designed to assess wilderness users' feelings about the above issues. Specifically, information relevant to the following questions was elicited:

(1) To what extent is fishing a primary interest of wilderness area users?
(2) How do the respondents view the current fisheries practices?
(3) How do the respondents evaluate the wilderness area in terms of:
  (a) its inherent natural beauty.
  (b) the impact of human use.
  (c) their enjoyment of their current outing.

A sample of Desolation Wilderness users was taken from lists of 1973 permit holders compiled at El Dorado National Forest Supervisors Station at Placerville, Pacific Ranger Station at Pollock Pines, and Lake Valley Ranger Station at South Lake Tahoe. The survey was sent to each permittee with a stamped, self-addressed, return envelope. The time period covered by the survey was from June through October, 1973. In all, 406 completed surveys were returned: 60% of the surveys mailed.

The survey instrument is constructed of statements called items which convey a feeling or an idea about various aspects of Desolation Wilderness. Each respondent is asked to express an opinion by circling the appropriate category on the response scale for each item (Table 1).

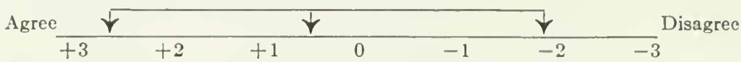
In the analysis, the items were divided into two conceptual groups or information fields. One field consisted of all those items which assess respondents' impressions of different aspects of the Desolation Wilderness: for example, its natural beauty, its freedom from the impact of human use, and its comparison with other wilderness areas which the respondents had visited. The second field of items concerned the respondents' orientations toward the wilderness area fisheries resources; in particular their own interest in fishing and their attitude toward current fisheries management practices.

The items in each of the two fields were factor analyzed by the Thurstone Centroid method to determine the principal orthogonal factors (Nunnaly 1967). Each factor is composed of a linear combination of the items (variables), but only those items highly correlated (high factor

TABLE 1. **Items Highly Correlated with the Dimension "Degree of Angling Interest".** The mean response to each item is indicated by the center arrow (↓). The distance between the two outside arrows (↓ ↓) corresponds to the mean plus and minus one standard deviation, and illustrates where the 68% of the people responded on the scale for each item. Factor loadings indicate the correlation of the item with the factor.

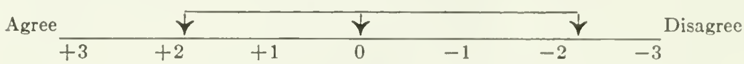
Factor Loadings

I derive much pleasure from fishing in a wilderness area.



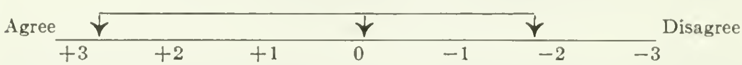
0.836

I usually seek out a good fishing water to camp near.



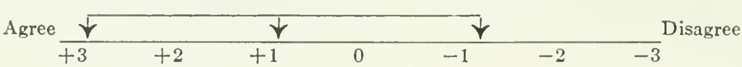
0.830

A couple of hours of fishing just "tops off" my day in the back country.



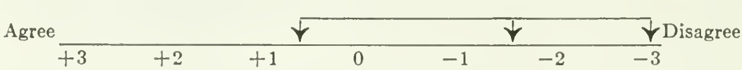
0.821

I view fishing as an added bonus to my wilderness trip.



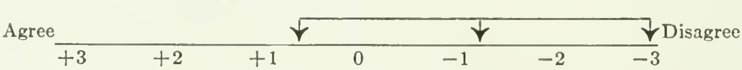
0.730

I depend on fish for a major portion of my food in a wilderness area.



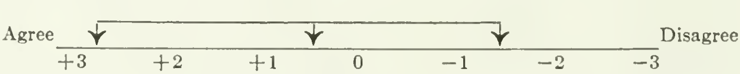
0.704

If fishing were not available in Desolation Wilderness Area, I would choose some other place to do my backpacking.



0.699

Fish and Game should intensify their management to better maintain or improve fishing in wilderness area lakes.

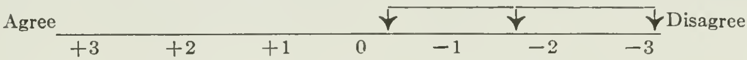


0.593

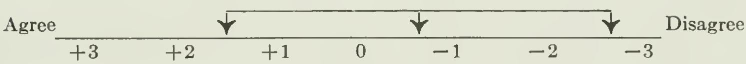
TABLE 2. Items Highly Correlated with the Dimension "Attitude Toward Fisheries Management". The mean response to each item is indicated by the center arrow (↓). The distance between the two outside arrows (↓——↓) corresponds to the mean plus and minus one standard deviation and illustrates where the 68% of the people responded on the scale for each item. Factor loadings indicate the correlation of the item with the factor.

Factor Loadings

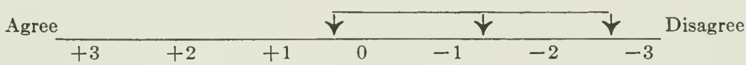
Knowing that Fish and Game planted lakes in Desolation Wilderness Area with fingerling trout would be enough to ruin my appreciation for this wilderness area. 0.836



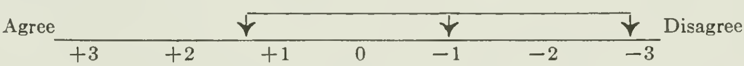
If lakes are naturally barren of fish in a wilderness area they should remain so. 0.761



Wilderness area lakes should be left alone and not managed by Department of Fish and Game. 0.752



The witnessing of Fish and Game planting fingerling trout by airplane in a wilderness area would be enough to seriously interrupt the peace and relaxation I receive from a hiking trip. 0.730



Planting of fingerling trout would enhance the attractiveness of a naturally barren wilderness area lake. −0.715

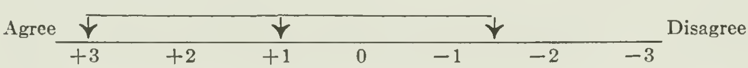
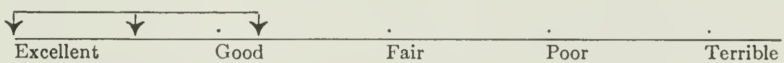


TABLE 3. Items Highly Correlated with the Dimension "Inherent Natural Beauty". The mean response to each item is indicated by the center arrow (↓). The distance between the two outside arrows (↓——↓) corresponds to the mean, plus and minus one standard deviation, and illustrates how the 68% of the people responded to each item. Factor loadings indicate the correlation of the items with the factor.

Factor Loadings

Beauty of general area. 0.846

Aesthetic qualities of the lakes and streams. 0.710



loading) with each factor were used to construct a scale for each factor. Each score on the scale is called a scale score and is obtained by a linear summation of the numerical values assigned by the respondent to the response scale for each of the highly correlated items. All the possible values for the scale scores compose the scale. This scale is called a dimension. This procedure results in scale scores which provide an effective measure of the respondents' attitudes (Nunnaly 1967). The analysis produced three independent evaluation dimensions, and two independent dimensions related to attitudes toward the wilderness area fisheries and their management. These dimensions are discussed below.

RESULTS

Angling and Fisheries Management Dimensions

Two of the dimensions that emerge from the factor analysis are described as "degree of angling interest" and "attitude toward fisheries management". The practical meaning of these dimensions can be inferred from inspection of the items in Tables 1 and 2.

People with high scores on the dimension "degree of angling interest" consider angling to be of importance in their wilderness area activities, while those with low scores do not. Thus for some users, angling is a major element in the enjoyment of their outing, and fishing would have to be available to attract them to the Area. For others, fishing is a pleasurable experience in the back country, but not an activity of primary importance. Conversely, people with low scores of this dimension do not regard fishing of any importance to their trip, and the availability of fishing is not a factor in their selection of the Desolation Wilderness.

The distribution of scale scores for this dimension is most dense near the center of the scale (Figure 1). When the scale scores are mapped onto the item scale it can be seen that 36% of the respondents reported little or no interest in angling, while 40% expressed moderate to strong interest. The remaining 24% expressed only an occasional or very secondary interest.

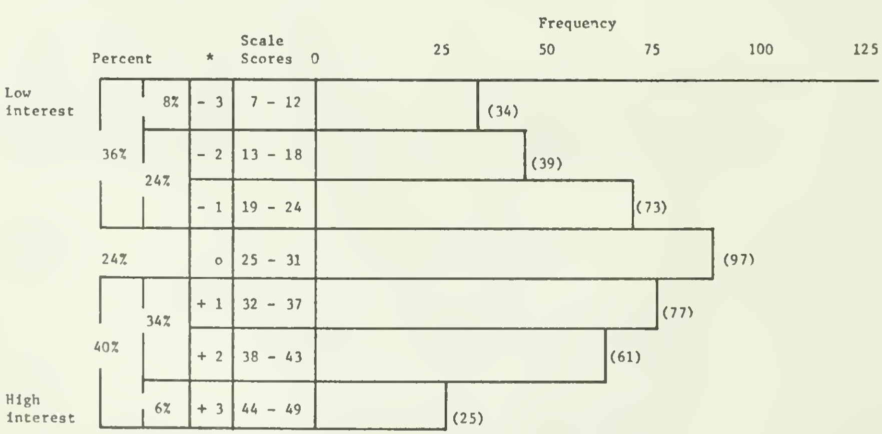


FIGURE 1. Frequency distribution of scale scores for the dimension "degree of angling interests". * Original item scale

People with high scores on the dimension "attitude toward fisheries management" support the concept of fisheries management in a wilderness area. For them, the present fisheries management plan would seem to enhance the attractiveness of the Area. Conversely, people with low scores on the dimension regard management as a negative factor, and feel that fisheries management is undesirable, violating the true essence of a wilderness area. The distribution of scale scores for this dimension is most dense at the positive end of the scale (Figure 2). When the scale scores are projected onto the item scale it can be seen that 68% of the respondents favor fisheries management, 19% are neutral, and only 13% have a negative view of fisheries management.

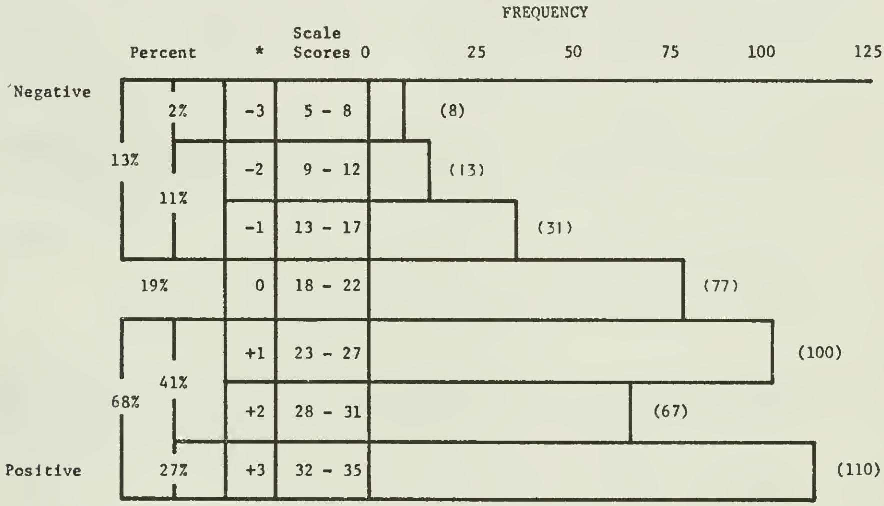


FIGURE 2. Frequency distribution of scale scores for the dimension "attitude towards fisheries management".
* Original item scale

Evaluation of Wilderness Experience Dimensions

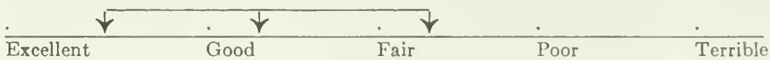
Three dimensions that emerge from factor analysis are described as "evaluation of inherent natural beauty", "freedom from impact of human use", and "overall evaluation of the current trip." The practical meaning of these dimensions can be inferred from the inspection of the items in Tables 3, 4, and 5.

Items associated with the dimension "evaluation of the inherent natural beauty" of the Area do so in a broad sense (Table 3). These items concern the general setting of the Area, its panoramic vistas, and the aesthetic qualities of lakes and streams. Respondents who scored high on this dimension feel that the Area is rich in natural beauty. Conversely, those with low scores feel it is lacking in this respect. The distribution of scale scores for this dimension is most dense at the positive end of the scale (Figure 3). The mapping of the scale scores back to the item scale indicates that virtually 100% of the people rate the inherent natural beauty of Desolation Wilderness as either good or excellent.

The dimension "freedom from impact of human use" is comprised of items which elicit wholly subjective evaluations by the respondents. Whether or not a respondent regards the effects of human use as aversive depends upon his personal orientations, rather than upon objective criteria. For example, a given density of use may be perceived as excessive

TABLE 4. **Items Highly Correlated with the Dimension "Freedom from Impact of Human Use".** The mean response to each item is indicated by the center arrow (↓). The distance between the two outside arrows (↓ ↓) corresponds to the mean, plus and minus one standard deviation, and illustrates how the majority of the people responded to each item. Factor loadings indicate the correlation of the item with the factor.

Item	Factor Loadings
Freedom from excessive crowding.	0.780



Item	Factor Loadings
Tranquility and peacefulness.	0.736

Item	Factor Loadings
Courtesy of fellow campers.	0.709

Item	Factor Loadings
Cleanliness and absence from litter.	0.690

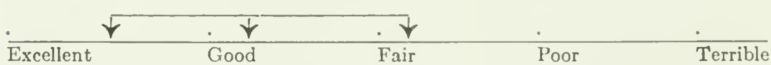
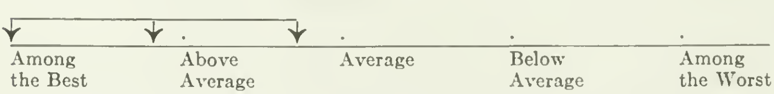
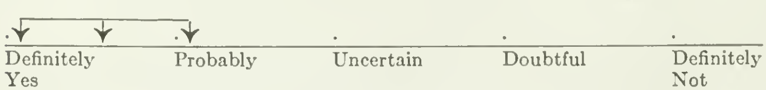


TABLE 5. **Items Highly Correlated with the Dimension "Overall Evaluation of Current Trip".** The mean response to each item is indicated by the center arrow (↓). The distance between the two outside arrows (↓ ↓) corresponds to the mean, plus and minus one standard deviation, and illustrates where the majority of the people responded to each item. Factor loadings indicate the correlation of the item with the factor.

Item	Factor Loadings
Among all the backpacking you have done, how do you rate your trip to Desolation Wilderness Area in your overall estimation?	0.871



Item	Factor Loadings
If possible, do you plan to return to the Desolation Wilderness Area?	0.794



crowding by one person, but completely tolerable to another. In no way was there an attempt by the respondents to assess the degree of possible ecological damage. The scale score distribution for this dimension is most dense near the positive end of the scale (Figure 4). A mapping of the scale score onto the item scale suggests that 67% of the respondents rated Desolation Wilderness good and excellent in its freedom from adverse effects from human use, 30% rated it as fair, and 3% rated it as terrible and poor. From the standpoint of the personal perceptions of the respondents, the Area is perceived quite favorably.

The scale "overall evaluation of current trip" provides a measure of the respondents' enjoyment of their current outing in the Area. Naturally anyone scoring high on this dimension enjoyed his visit to Desolation Wilderness: the converse is true for those who didn't score high. The densest portion of the distribution of scale scores is at the positive end of the scale (Figure 5). When the scale scores are mapped onto the original scale it can be seen that 94% of the respondents were highly satisfied, and only 6% gave average or poor ratings. We concluded that for nearly all users, the Desolation Wilderness Area is a source of true enjoyment.

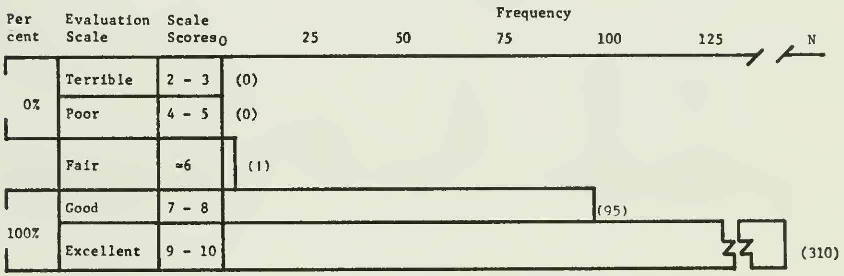


FIGURE 3. Frequency distribution of scale scores for the dimension "evaluation of the inherent natural beauty".

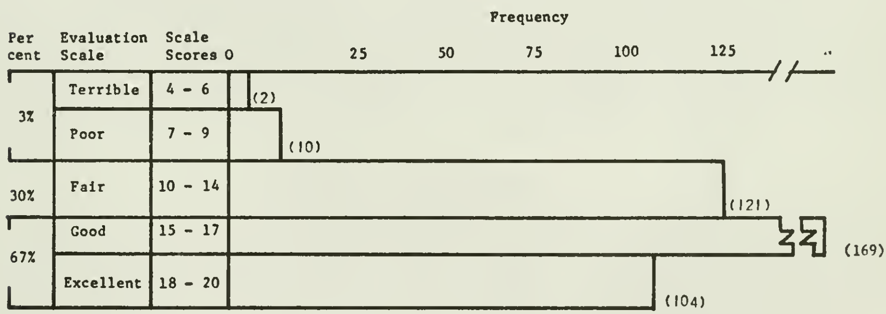


FIGURE 4. Frequency distribution of scale scores for the dimension "freedom from impact of human use".

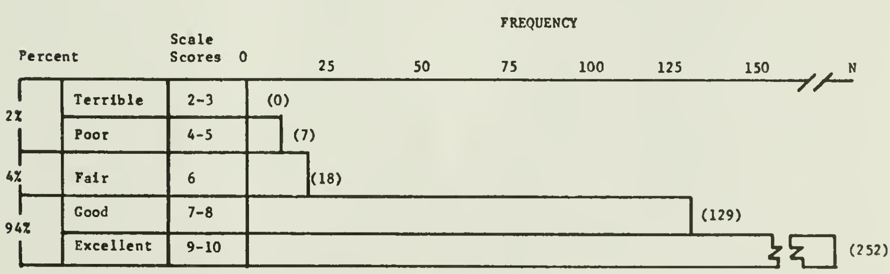


FIGURE 5. Frequency distribution of scale scores for the dimension "overall evaluation of current trip".

TABLE 6. Analysis of the Relation of Angling and Fisheries Management Dimensions to the Evaluation Dimensions.

Angling and fisheries management dimensions		N	Evaluation dimensions: Evaluates freedom from impact of human use	Evaluates inherent natural beauty	Overall evaluation of current trip
Attitude toward fisheries management	NEGATIVE	26	14.96	9.15	8.46
		32	14.91	9.13	8.59
		91	15.54	9.19	8.64
		113	15.42	9.19	8.70
	POSITIVE	144	16.01	9.30	8.83
			F = 1.8391 (NS)*	F = 0.4494 (NS)	F = 0.6704 (NS)
Degree of angling interest	LOW	51	15.90	9.29	8.78
		95	15.32	9.19	8.58
		129	15.70	9.25	8.85
		83	15.58	9.24	8.65
	HIGH	48	15.48	9.10	8.58
			F = 0.4625 (NS)	F = 0.3526 (NS)	F = 0.8397 (NS)

* NS = Not significant, $P > .05$.

Relationship Between Fish Resource Dimensions to Evaluation Dimensions

This portion of the analysis is concerned with two questions. First, are respondents' attitudes toward fisheries management related to their evaluations of this wilderness area? Specifically, we wanted to determine if persons with negative attitudes toward fisheries management practices gave low ratings to their experience in Desolation Wilderness. If this were the case, then it could be inferred that existing fishery management reduced the quality of the wilderness experience for some respondents—a contention expressed by some participants in the discussion between the U.S. Forest Service and California Department of Fish and Game. To answer this question, the respondents were divided into five subgroups on the basis of their "attitude toward fisheries management" scores, then the mean value for each of the subgroups on the three evaluation dimensions were computed. Analysis of variance indicated no significant differences in subgroup means of any of the evaluation dimensions (Table 6). We may conclude, therefore, that there is not relation between attitudes toward fisheries management practices and the respondents' evaluations of Desolation Wilderness. It thus can be inferred that present practices are not perceived as having a negative impact on the "essence of wilderness", nor as detracting from the enjoyment of the Area.

Secondly, is the degree of the respondents' interest in angling (as part of their wilderness area experience) related to their evaluations of the Area? Again, the respondents were divided into five subgroups on the basis of their "degree of angling interest" scores, and the means for each such group on the three evaluation dimensions were computed as above. As can be seen from Table 6, there was no significant relationship between evaluation dimensions and degree of angling interest. It can be inferred from these results that enjoyment of the Area is not related to degree of angling interest.

DISCUSSION

An effective method of reducing use in Desolation Wilderness would be to discontinue the stocking of fingerling trout to allow the fisheries to decline. This proposition rests on two related assumptions: first, current users are attracted to the Area by their interest in angling; and second, that a deterioration of the fisheries would reduce use by eliminating those interested in angling.

The information obtained from this survey clearly does not support the first assumption and by inference is also contrary to the second. Sixty percent of the respondents expressed no interest in angling (Figure 1); this proportion of users would be unaffected by a change in fishery potential. While 40% of the respondents expressed some interest in angling, only 6% indicated a strong interest. Note that the expression of some angling interest does not imply that angling was a primary reason for selecting Desolation Wilderness or that declining fisheries would deter the entire 40% who expressed an interest. The fact that enjoyment of the Area was not related to the degree of angling interest (Table 6) would indicate that most do not consider angling of prime importance. Hendee, Clark and Dailey (1974) found that while 43% of the people they surveyed fished at lakes in the back country of Washington state's Snoqualmie and Wenatchee national forests, most people who fished did so on a casual or incidental basis. If the fisheries were allowed to decline in Desolation Wilderness, we would expect at most a 6% decline in use.

Participants suggested in discussions between the U.S. Forest Service and the Department that the present fisheries management, principally aerial planting of fingerling trout, would reduce the quality of a "natural experience" for the wilderness visitor. Implicit in this feeling is that any foreign organism introduced into waters of Desolation Wilderness would not be "natural" and thus, the true essence of a wilderness would be lost. Items in Table 2 reflect these feelings. The information obtained from this survey, however, clearly demonstrates that for most visitors to Desolation Wilderness the present fisheries management does not reduce the quality of a "natural experience". Only 17% of the respondents held negative attitudes toward this concept (Figure 2); 2% were highly negative. In addition, scores on the wilderness evaluation dimensions were not related to scores on the "attitude toward fisheries management" dimension, indicating that the present fisheries management does not detract from their enjoyment of the Area. We conclude, therefore, that for most the present fisheries management practices do not violate the true essence of a wilderness area.

Aerial planting of fingerling trout is a fisheries management practice that is becoming a keen issue between the agencies involved in the management of wilderness and national park areas because of the sight and noise intrusion by the aircraft. Some have argued that this intrusion is enough to ruin someone's trip. Others have stated that the aircraft spends so little time in the Area that few would have a chance to experience the intrusion. Although not researched specifically in this study, the item in Table 2 regarding aerial planting would indicate that for most this experience would not be aversive. Whether people can actually relate to this experience is difficult to determine because the aircraft spends, at most, 1½ hours per year over the Area. Most people who indicated they would be disturbed by this experience probably objected on philosophical grounds rather than an actual aversive experience.

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Calif. Fish and Game 62(3): 179–186. 1976.

SOME EFFECTS OF CHANNELIZATION ON THE FISHES AND INVERTEBRATES OF RUSH CREEK, MODOC COUNTY, CALIFORNIA [1]

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Channelized and unchannelized sections of the lower 7 km (4.3 miles) of Rush Creek, Modoc County, California were compared to determine the impact of channelization on fish populations, especially those of trout (*Salmo gairdneri* and *S. trutta*) and the rare endemic Modoc sucker (*Catostomus microps*), and invertebrate populations. Fish were captured with a backpack electrofisher, which provided a representative sample by numbers of the species present, although large fish were more vulnerable to capture than small fish. Channelized sections contained fewer and smaller trout, as well as a lower biomass, than the unchonnelized sections. Modoc sucker numbers and biomass were also lower in the channelized sections. Only Pit sculpin (*Cottus pitensis*) were consistently more numerous in the channelized sections. Overall, total fish biomass in the chonnelized sections was less than one-third of that in the unchannelized sections. The biomass of invertebrates in the channelized sections was found to be less than one-third of that in the unchannelized sections. The invertebrate species composition of the two areas was also different.

INTRODUCTION

The channelization of streams for flood control is a common procedure in California as well as elsewhere in North America. Channelization converts a meandering stream with alternating pools and runs into a straight ditch with continuous runs and high banks (Funk and Ruhr 1971). The negative effects of channelization on most fish and invertebrate populations are widely recognized, but poorly documented (Schneberger and Funk 1971; Barton, et al, 1972; Wilkenson 1973). In particular, there is a lack of documentation of the effects of small-scale channelization on the biota of California streams, especially small coldwater streams. This paper reports the effects of channelization on the fish and invertebrates of Rush Creek, Modoc County. Rush Creek in most respects is typical of the small trout streams of the Pit River system of northeastern California, but it is also uniquely important as the principal home of the rare Modoc sucker, *Catostomus microps* (Moyle and Marciochi. 1975). The differences in fish species and numbers between the channelized and unchannelized sections of stream were first noticed in 1973 while I was collecting information on the Modoc sucker. I returned to the study area in 1974 to obtain fish and invertebrate biomass estimates and to validate the electrofishing procedure.

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[1] Accepted for publication February 1975.

STUDY AREA

Rush Creek, Modoc County (T 39N, R 9E), is a tributary of Ash Creek which in turn drains through extensive marshlands into the Pit River. It is a small (summer flows, 200 to 250 l/sec; 7–9 cfs), moderately warm (summer temperatures, 20 to 24C; 68 to 75F), permanent stream. The study area consisted of the lower 7 km (4.3 miles) of the creek, from its junction with Johnson Creek, its only large tributary, to its mouth at Ash Creek. Most of the creek in the study area is bordered by open or lightly wooded pastureland, although about 1.2 km (.75 mile) is heavily wooded. Both banks of the creek are privately owned and used as pasture for sheep and cattle. Fishing pressure is light because the landowners usually deny anglers access to their land. In the summer, much of the flow in the lower reaches of the study area is diverted for pasture irrigation. In the winter, the flows are occasionally high enough to threaten highway bridges and flood the bordering pastureland. Portions of the stream in the study area were channelized in an effort to control high winter flows. Landowners constructed most of the channelized sections with the technical assistance of the Soil Conservation Service (D. W. Patterson, Soil Conservation Service, pers. commun.).

The longest channelized section extends from the mouth of Johnson Creek downstream 1.6 km (.98 mile). This portion of the stream was straightened in 1969 and the soil deposited on both banks forming spoil-bank levees 2 to 4 m high (6 to 10 ft). The bottom now consists primarily of gravel and cobbles, although bedrock has been exposed in many places. During the summer, the water forms a continuous riffle 25 to 30 cm deep (10 to 12 inches). In the unchannelized, heavily wooded section immediately below this section, the creek consists of pools up to 1.2 m deep (4 ft) alternating with gravel-bottomed riffles between undercut banks. In this area, the water is heavily shaded most of the day and many bushes and logs extend into the water.

Below the wooded section, the stream is again channelized for about 250 m (820 ft) downstream from a highway bridge. It then meanders unchannelized through overgrazed pastureland for about 1 km (.62 mile). Although shade is lacking, there are large, deep pools and undercut banks. Another 500 m (1650 ft), channelized in 1968, follows. Below this, the stream again assumes its pool and riffle character for another kilometer and is bordered by numerous trees and bushes.

For the final 2 km (1.2 miles), the creek flows through open, often boggy, pastureland. Although a few large pools still exist, much of this stretch has been channelized. The most recent dredging activity was completed in June 1973, immediately prior to the study. Stream flows were generally low in most of this section due to an irrigation diversion at its beginning.

METHODS

Fish were collected from the study area on July 13–15, 1973, and on June 9–10, 1974, with a Smith-Root Type V backpack electrofisher. One worker operated the unit, while two others caught the fish with dip nets. In 1973, fish were taken from 22 unblocked subsections of stream, each 33 m (100 ft) long, from all parts of the study area. Each subsection was electrofished once and the time the unit was in operation recorded. Eleven subsections (363 m; 1100 ft) of channelized stream were electrofished for a total of 2143 seconds, while 11 unchannelized subsections (363 m; 1100 ft) were

electrofished for a total of 2466 seconds. The standard length of all fish captured was measured to the nearest millimeter.

In 1974, all sampling for both fish and invertebrates was in the uppermost channelized section and the heavily wooded, unchannelized section immediately below it. These sections were chosen because the unchannelized section was the least disturbed by livestock activity of all such sections in the study area. Two subsections, each 61 m (200 ft) long, were sampled in the channelized area and two subsections, one 61 m (200 ft) long and the other 43 m (142 ft) long, were sampled in the unchannelized area. The 43 m subsection was made necessary by stream contours which dictated where block seines could be placed to effectively prevent the escape of fishes from the sample area. The upper and lower ends of each section were blocked with the seines. Each section was then electrofished three times in succession and the fish removed during each effort. Time spent electrofishing was not recorded due to a malfunction of the timer on the unit. All fish were weighed to the nearest gram with Pesola pencil scales and measured to the nearest millimeter (standard length) as they were in 1973.

Also in 1974, 20 samples of invertebrates were taken from both the channelized and unchannelized sections, from areas not electrofished, with a .093 m^2 (1 ft^2) Surber sampler. All samples were preserved in a 4% formaldehyde solution. The samples were sorted and the invertebrates identified, where possible, to genus with the keys in Usinger (1956). All invertebrates belonging to the same taxon in each of two series of collections were blotted dry and then weighed to the nearest .01 g on an analytical balance within 3 weeks of the collection date.

RESULTS

Six species of fish and one lamprey were collected in the study area: rainbow trout, brown trout, speckled dace (*Rhinichthys osculus*), Pit sculpin, Modoc sucker, Sacramento sucker (*Catostomus occidentalis*), and Pit-Klamath brook lamprey (*Lampetra lethophaga*). Sacramento suckers were found only as young-of-the-year in the lowest section. Pit-Klamath brook lampreys were common as ammocoetes but only adult or transforming individuals were included in the data analysis because the ammocoetes usually escaped through the meshes of the dip nets.

The 1973 fish samples showed that average size and numbers of rainbow trout, average size of brown trout, and numbers of Modoc suckers were less in the channelized sections than they were in the unchannelized sections, while the percentages of Pit sculpins were greater (Table 1). The catch per second data show that only brown trout and Pit sculpin were actually more abundant in the channelized sections and that fish were much more abundant overall in the unchannelized sections. A similar pattern appears in the catch (number) data from the 1974 samples, with the exception that speckled dace were more numerous in the channelized sections (Table 2). Since many of the speckled dace captured possessed breeding tubercles, it is likely that they had moved up into the channelized sections to spawn. Although more adult lampreys were collected in the unchannelized subsections in 1974, in both 1973 and 1974 ammocoetes seemed most abundant in silty areas along the edges of the channelized subsections and in the silt filled pools that were usually present at the end of the channelized sections. Chi square tests showed the differences in percent species composition between the channelized and unchannelized

subsections were significant at the .05 level (1973 $\chi^2 = 60.42$, 5 d.f.; 1974 $\chi^2 = 425.60$, 5 d.f.). The 1974 biomass data also reflect the differences in species composition between the subsections. Eighty percent of the fish biomass in the unchannelized subsections was rainbow and brown trout, compared to 33% in the channelized subsections. Even Pit sculpins, which were more abundant in the channelized sections, tended to be larger in the unchannelized sections. The total biomass of fish in the unchannelized subsections is nearly 3.4 times that in the unchannelized subsections.

TABLE 1. **Numbers, Percent of Numbers, Average Standard Lengths, and Catch per Second for Fishes Taken by Electrofishing From Channelized and Unchannelized Sections of Rush Creek, Modoc County, July 13–15, 1973.** The channelized sections were electrofished a total of 2143 seconds, the unchannelized sections, 2466 seconds.

	Number	Percent	Average standard length (mm)	Catch per second
Brown Trout				
Channelized	24	9	23	.011
Unchannelized	17	4	70	.007
Rainbow Trout				
Channelized	29	11	46	.014
Unchannelized	127	30	60	.051
Pit Sculpin				
Channelized	65	25	31	.030
Unchannelized	52	12	29	.021
Speckled Dace				
Channelized	142	54	24	.065
Unchannelized	192	45	18	.078
Modoc Sucker				
Channelized	1	<1	61	<.001
Unchannelized	20	5	67	.002
Sacramento Sucker				
Channelized	4	2	10	.002
Unchannelized	16	4	13	.006
Total				
Channelized	265	100	--	.125
Unchannelized	424	100	--	.174

Repeated sampling of the four subsections in 1974 indicated that single electrofishing samples provided a fairly reliable indication of the composition of the fish community (Table 3). A Spearman rank correlation test (Steel and Torrie 1960), showed that there was no significant difference at the .05 level between the percent composition by numbers of the catch taken on the first electrofishing attempts and the percent composition of the total catch ($r = .36$, 4 d.f.). However, since only 44% of the fish by number but 60% of the fish by weight were taken in the first attempt, it appears that the initial sample is somewhat biased towards larger fish, especially trout. Observations of the netters on the number of fish they saw but did not capture indicated that nearly all of the fish in the subsection were taken in the three attempts.

TABLE 2. **Comparisons of Numbers Taken, Percentage of Total Catch, Numbers Taken Per Meter of Stream, Average Standard Length, Grams, Percent Grams, and Grams Per Meter of Stream of Fishes Taken From Channelized and Unchannelized Subsections of Rush Creek, Modoc County, June 9–10, 1974.** The channelized subsections sampled were 120 m long totol and the unchannelized subsections 103 m long total.

	Number	Percent number	Number per meter	Average standard length (mm)	Grams	Percent total grams	Grams per meter
Brown trout							
Channelized	8	4	0.07	135	296	21	3.22
Unchannelized	7	6	0.07	156	760	16	7.38
Rainbow trout							
Channelized	6	3	0.05	123	176	12	1.58
Unchannelized	33	26	0.32	159	2991	64	29.04
Pit sculpin							
Channelized	49	25	0.44	57	261	18	2.35
Unchannelized	41	32	0.40	74	430	9	4.17
Speckled dace							
Channelized	131	66	1.18	58	515	36	4.64
Unchannelized	29	23	0.28	43	53	1	0.51
Modoc sucker							
Channelized	3	2	0.02	150	188	13	1.69
Unchannelized	13	10	0.13	99	430	9	4.17
Brook lamprey							
Channelized	1	<1	0.01	149	6	<1	0.05
Unchannelized	4	3	0.04	143	30	1	0.29
Total							
Channelized	198	100	1.77	--	1442	100	13.53
Unchannelized	127	100	1.24	--	4694	100	45.56

Despite the problems of obtaining a representative sample of benthic invertebrates using a Surber sampler (discussed in Hynes 1970), the differences observed between the channelized and unchannelized sections probably reflect real differences because of the smallness of the stream, the number of the samples, and the size of the differences observed (Table 4). Spearman rank correlation tests showed significant differences, at the .05 level, ($r = .64$, 18 d.f.) between channelized and unchannelized sections in numbers per square meter, grams per square meter, and percent composition by grams. The samples from riffles in the unchannelized section had over three times the biomass of invertebrates of the samples from the channelized section. The invertebrates with the greatest biomass in the unchannelized section were stonefly nymphs (Plecoptera), followed by caseless caddisfly larvae (Trichoptera: *Hydropsyche, Rhacophila*). The invertebrates with the greatest biomass in the channelized sections were caddisfly larvae, both case building and caseless, followed by mayfly nymphs (Ephermeroptera), and stonefly nymphs.

DISCUSSION

The results of this study confirm more extensive, but similar studies in Montana (Whitney and Bailey 1959; Elser 1968), which showed that channelization greatly reduces the average size and number of trout per surface area of stream. It can be concluded, therefore, that the results observed are due to channelization. In Rush Creek, trout biomass was over

seven times greater in unchannelized sections than it was in channelized sections. There was also a significant reduction in Modoc sucker and Pit sculpin biomass in the channelized sections, although the biomass of speckled dace increased. However, the effects of channelization reported here can only be considered as minimal for the following reasons: (1) the channelized sections studied were 4 or 5 years old, so their fish and invertebrate fauna had had ample time to partially recover; (2) the study did not take into account the reduction of stream length caused by the straightening of the stream meanders; (3) a high proportion of the unchannelized sections of lower Rush Creek had been severely disturbed by the heavy grazing of livestock on the surrounding lands, with the concomitant removal of streambank vegetation and trampling of the streambanks themselves; and (4) channelization tends to alter the geomorphology of the unchannelized sections of stream below the channelized sections through accelerated erosion and siltation (Curry 1972).

TABLE 3. Numbers and Grams of Fishes Taken and Removed in Three Successive Electrofishing Runs in Four Blocked Sections of Rush Creek, Modoc County, June 9–10, 1974.

	Sample Run							
	1		2		3		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Brown trout								
Number	10	7	4	4	1	1	15	5
Grams	917	25	165	10	35	4	1117	18
Mean wt. (g)	92	--	41	--	35	--	74	--
Rainbow trout								
Numbers	22	15	14	12	3	4	39	12
Grams	1855	50	972	57	340	43	3167	51
Mean wt. (g)	84	--	69	--	113	--	81	--
Pit sculpin								
Numbers	42	29	30	26	18	26	90	28
Grams	298	8	266	16	125	16	689	11
Mean wt. (g)	7	--	9	--	7	--	8	--
Speckled dace								
Numbers	56	39	64	56	40	59	160	49
Grams	228	6	217	13	123	16	568	9
Mean wt. (g)	4	--	3	--	3	--	4	--
Modoc sucker								
Numbers	12	8	1	1	3	4	16	5
Grams	410	11	60	4	148	19	618	10
Mean wt. (g)	34	--	60	--	49	--	39	--
Brook lamprey								
Numbers	1	1	1	1	3	4	5	2
Grams	3	<1	14	<1	19	2	36	1
Mean wt. (g)	3	--	14	--	6	--	7	--
Total								
Numbers	143	100	114	100	68	100	325	100
Grams	3711	100	1694	100	790	100	6195	100
Mean wt. (g)	26	--	15	--	12	--	19	--

Presumably most of the loss of fish carrying capacity observed from the channelized sections of Rush Creek was caused by the loss of pools, over-

hanging bushes, large boulders, and other cover. Only small riffle-dwelling fish (speckled dace, Pit sculpin) that were able to use the scant cover provided by small rocks and turbulent water maintained large populations in the channelized sections. The over three-fold reduction in the biomass of invertebrates per square meter of riffle undoubtedly also contributed to the low fish populations in the channelized sections since most of the invertebrates are used by the fishes for food. This reduction in invertebrate biomass is reflected in the over three-fold reduction in fish biomass per meter in the channelized sections (Table 2). The apparent difference in the composition of the invertebrate fauna may also have been a contributing factor to the lower fish biomass. For example, the limnephilid caddisfly larvae that were the most abundant invertebrates in the channelized sections are, because of their large size and heavy cases, largely unavailable as food to the small fishes that dominated the sections.

TABLE 4. Numbers and Grams of Invertebrates Per Square Meter From Channelized and Unchannelized Sections of Rush Creek, Modoc County, June 9–10, 1974.

	Sections					
	Unchannelized			Channelized		
	Numbers per square meter	Grams per square meter	Percent total grams	Numbers per square meter	Grams per square meter	Percent total grams
Plecoptera						
Acroneuria	15.07	2.42	47	2.69	0.29	17
Isoperla	4.31	0.05	1	0.54	0.01	1
Ephemeroptera						
Heptagenia	16.68	0.18	3	5.92	0.08	5
Iron	2.69	0.05	1	1.08	0.01	1
Ephemerella	4.31	0.11	2	1.08	0.03	2
Ameletus	15.07	0.07	1	17.22	0.08	5
Tricorythodes	3.22	0.01	<1	3.77	0.02	1
Unidentified	0.00	0.00	0	1.61	0.05	3
Trichoptera						
Limnephilidae						
species A	0.54	0.17	3	2.15	0.36	21
species B	3.22	0.06	1	15.07	0.12	7
Brachycentrus	3.22	0.01	<1	1.08	0.01	1
Hydropsyche	54.36	1.23	24	16.68	0.46	27
Rhyacophila	2.15	0.05	1	2.69	0.02	1
Unidentified	0.00	0.00	0	3.23	0.02	1
Diptera						
Limnophilus	5.92	0.35	7	4.31	0.02	1
Chironomidae	2.15	0.01	<1	4.31	0.02	1
Simuliidae	6.44	0.02	<1	0.00	0.00	0
Coleoptera						
Eubrianax	2.69	0.02	<1	0.00	0.00	0
Elmidae	1.61	0.02	<1	1.08	0.01	1
Noteridae	1.08	0.01	<1	0.00	0.00	0
Odonata						
Zygoptera	0.54	0.01	<1	0.00	0.00	0
Oligochaeta	3.22	0.19	4	0.00	0.00	0
Gordiida	0.54	0.12	2	0.00	0.00	0
Total	149.03	5.15	100	84.51	1.61	100

It is obvious that the severe reduction in fish populations, especially those of game fishes and rare native fishes, should be taken into account before a stream is channelized. The impact of any channelization project should be considered not only in light of its immediate effects on the stream section being channelized but also in light of its effects when combined with other changes (especially other channelization projects) of the entire stream system. Over half of the lower 7 km (4.3 miles) of Rush Creek has been channelized, not as one coordinated project but as a series of small changes over a number of years. Although the effect of each individual project has been minor relative to the stream as whole, the impact of all the projects combined on the fish populations has been drastic. The Pit River system contains many similar small streams, some of which have also been partially channelized. Future channelization projects, major and minor, should thus take into account the long term degradation of the trout fishery likely to ensue over the entire system, as well as the deleterious effects on the system's endemic nongame fish fauna, particularly the Modoc sucker.

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CONTRIBUTION OF PHYTOPLANKTON, PERIPHYTON, AND MACROPHYTES TO PRIMARY PRODUCTION IN EAGLE LAKE, CALIFORNIA [1]

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The importance of phytoplankton, periphyton, and macrophytes to primary production in each of the three basins of Eagle Lake, California was considered. Phytoplankton and periphyton production were measured using the oxygen light and dark bottle method. Production by macrophytes was determined by harvesting at maximum biomass.

Although phytoplankton accounts for 89% of the annual carbon fixed in the south basin of Eagle Lake, periphyton and macrophytes contribute as much as one third of the primary production in the shallower north and central basins.

INTRODUCTION

There are numerous investigations of phytoplankton production in lakes, but other primary producers have generally been ignored. Two reasons are involved. First, limnetic phytoplankton has been assumed to be the most important group since the littoral zone occupies a small portion of the surface area of most lakes. A few estimates of littoral primary production (Straskraba 1963, Pieczyńska and Szczepańska 1966, Westlake 1966) have shown the importance of macrophytes and periphyton in ponds and lakes with an extensive littoral zone. Secondly, measurement of periphyton and macrophyte production is often indirect, involving changes in biomass over a period of time (Wetzel *et al.* 1972), and lacks the accuracy of the well established phytoplankton methodology. Recently oxygen and ^{14}C techniques have been developed to measure littoral production (Wetzel 1964*a*, Westlake 1966, Allen 1971). Although these direct measurements are more meaningful, problems of interpretation, intercalibration of methods, and adaptation of techniques to various habitats still prevent their wide usage (Wetzel 1964*b*).

The objective of this study was to determine the relative importance of each component of primary production in Eagle Lake, a very large but relatively shallow lake.

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Lake Description

Eagle Lake is located in the northern Sierra Nevada at 1557 m (5100 ft) elevation (Figure 1). Its high pH and electrical conductivity are characteristic of semi-desert lakes (Table 1). The north and middle basins are shallow, while the south is deeper; only the south stratifies during the summer. The seasonal inflow (mostly in winter and spring) and high summer evaporation result in a fluctuating lake level and variation in chemical characteristics. The lake is slightly alkaline and hardness results from moderately high concentrations of magnesium ion.

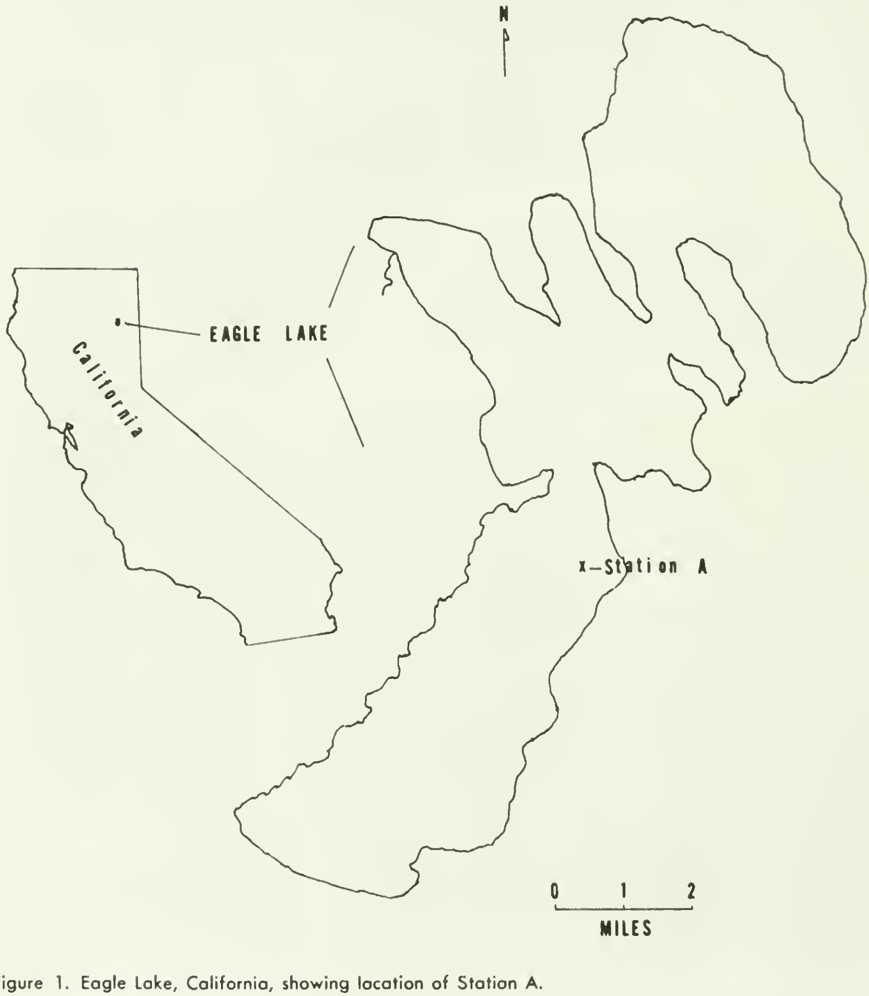

Figure 1. Eagle Lake, California, showing location of Station A.

TABLE 1. Limnological Characteristics of Eagle Lake, California, 1971–1972.

Alkalinity (mg/l as $CaCO_3$)		Hardness (mg/l as $CaCO_3$)		pH	Electrical Conductivity (μmhos/cm)	Area (ha)	Secchi disk visibility (m)	Maximum depth (m)	Mean depth (m)	Shoreline development
CO_3^{--}	HCO_3^-	Ca^{++}	Mg^{++}							
55	410	20	155	8.8–9.1	*ca.* 780	12,150	4–8	30.5	6.95	4.41

Eagle Lake lies in a geologically active area and the basin has apparently been altered several times by faulting or lava flows (Gester 1962). The shoreline is composed of vesicular basaltic boulders in exposed areas with granitic sand filling in protected bays.

Typical phytoplankton genera are *Fragilaria, Anabaena, Microcystis,* and *Pediastrum. Gomphonema* is the predominant genus of epilithic periphyton. Epiphytic genera include *Gomphonema, Bulbochaeta, Coleochaete,* and *Nostoc.*

Macrophytes are limited in their distribution, occurring primarily along the west shore as two dominant species, *Juncus balticus* and *Scirpus acutus. Juncus* extends from shore in dense bands to a depth of 2 m (6.5 ft) and *Scirpus* grows in water 2 to 5 m (5.6 to 16.4 ft) deep. Occasionally interspersed are *Potamogeton pectinatus, Polygonum amphibium, Ultricularia vulgaris,* and *Myriophyllum* sp.

METHODS

Phytoplankton primary production was measured using the oxygen light and dark bottle method with a 24-hr incubation period. This is a standard technique in which the sum of oxygen produced in the light bottle and oxygen consumed in the dark bottle approximates gross productivity (Vollenweider 1969). Measurement of dissolved oxygen before and after incubation was made with an oxygen meter. For each limnetic determination six pairs of bottles were incubated at 1.5-m (4.9-ft) intervals from the surface to the bottom of the lake. The resulting values of production per unit volume were integrated against depth to give a single value of productivity per unit surface area.

A permanent station (Station A) was established at the north end of the south basin (Figure 1). Production measurements were at irregular intervals but at least once monthly from April to November 1971. During the period 28 July–14 August 1971, a movable station was operated daily at different points throughout the lake. During the same time period, three determinations were made at Station A so that the comparability of Station A with data from other locations could be evaluated.

Littoral phytoplankton production was determined weekly during June and July 1971, at three stations in the macrophyte zone.

For measurement of periphyton production, artificial substrates (unglazed porcelain title) were suspended at depths of 0.5 m (1.6 ft) and 1.0 m (3.3 ft) among the macrophytes and on the bottom at depths of 1, 2, 4, and 5 m (3.3, 6.5, 13.1, and 16.4 ft) in rocky areas. Tiles were left 20 to 30 days to allow colonization comparable to that on the natural substrates. The oxygen light and dark bottle method was then used to determine production on the tiles, with a 24-hr incubation in the lake. Before incubation all but a delineated area of 50 cm^2 (8 $inches^2$) on the tile was scraped clean. A set of light and dark bottles without tiles was run simultaneously to correct for oxygen production by phytoplankton incubated with the tiles.

Surface area of epiphytic growth was estimated by multiplying the average underwater surface area per macrophyte by macrophyte density. Calculation of macrophyte surface area was based on the assumption that *Juncus* and *Scirpus* were cylinders with a diameter equal to their average diameter.

Area for growth of epilithic periphyton in the north and middle basins was determined by planimetering on a bathometric map the portion of

the lake with a depth less than 4 m (13.1 ft). Below 4 m flocculent sediments inhibit benthic growth. In the south basin, area for epilithic growth included the area with a depth less than 10 m (33 ft), which is the approximate euphotic zone.

Production by *Juncus* was determined by harvesting nine square meter (10.8 ft^2) plots at maximum biomass in August. Subsamples were taken, and ash-free, or organic weight, was determined by combustion at 550 C (1022 F). Because of the size of *Scirpus* (4 m) (13.1 ft) and the depth of the water, it was not possible to harvest measured plots. Several shoots were harvested, dried, and combusted to determine average organic weight per plant. This was multiplied by average density to estimate production per m^2. Area of the lake occupied by macrophytes was determined by assuming weed beds to be polygons. Their dimensions were measured from a boat using a speedometer and stopwatch. Carbon was assumed to be 46.5% of organic weight, an average value determined by Westlake (1966) for aquatic macrophytes.

Macrophytes die at Eagle Lake under the winter ice cover. However, both dominant species are perennial and green shoots are renewed annually from rhizomes. Contribution to growth from rootstocks was not measured. Since the macrophytes are subject to little grazing, estimates approximate net production.

The techniques used for measuring production for each component of the primary producers are those commonly accepted (Vollenweider 1969). When applied to a lake, this does involve mixing 24-hr measurements of production with long-term or annual measurements. Most confusion can be avoided by converting to a common unit of grams carbon produced per unit of lake surface area. In this study, the photosynthetic quotient (O_2 output/CO_2 uptake) was assumed to be unity, so that g oxygen $\times$ 0.375 = g carbon.

RESULTS AND DISCUSSION

Seasonal changes in limnetic phytoplankton production at Station A, corrected to represent a mean value for the whole lake ranged from 0.2 to 0.8 g carbon m^{-2} day^{-1} (0.02 to 0.07 g carbon ft^{-2} day^{-1}) (Figure 2). The dashed line represents an estimate for the ice-bound period, assuming productivity to be 15% of the late fall and early spring values, as found by Pieczyńska and Szczepańska (1966). Integration of Figure 2 gives 130 g carbon m^{-2} $year^{-1}$ (12 g carbon ft^{-2}) (Table 2). This estimate is conservative since production probably remained high immediately before and after ice cover rather than declining at a constant rate as assumed.

Phytoplankton production approached that of highly eutrophic Clear Lake, California, which had a mean production of 0.44 g carbon m^{-2} day^{-1} (0.04 g carbon ft^{-2}) and an annual production of 159.8 g carbon m^{-2} (14.8 g carbon ft^{-2}) (Goldman and Wetzel 1963). Eagle Lake had a higher mean production (during its ice-free period) than Clear Lake. However, water clarity was much greater than Clear Lake, where Secchi disk transparency can be less than 1 m (3.3 ft). Algal blooms were infrequent and short at Eagle Lake. The high production was distributed over a euphotic zone of about 10 m (32.8 ft), while the euphotic zone of Clear Lake was usually less than 3 m (9.8 ft).

Littoral phytoplankton production did not differ significantly at the three stations in the *Juncus* zone. However, it tended to decrease during the summer as macrophyte growth increased. Values varied from 0.75 g

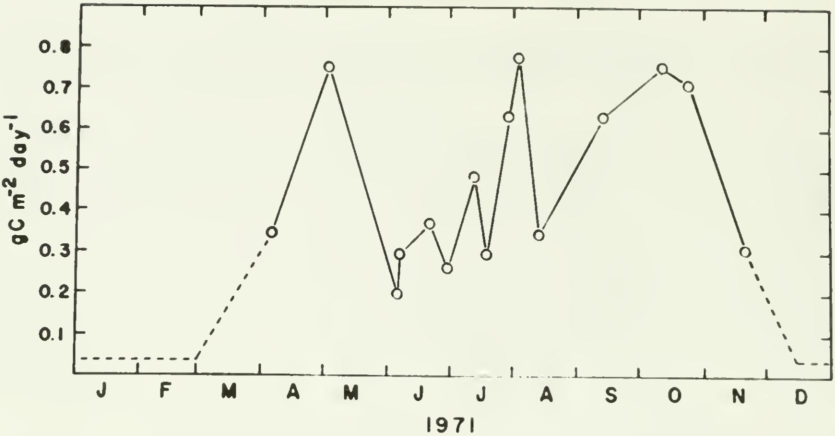

Figure 2. Seasonal changes in primary production (g C m^{-2} day^{-1}) by limnetic phytoplankton in Eagle Lake, California, 1971.

TABLE 2. **Estimates of the Contribution of Phytoplankton, Periphyton, and Macrophytes to Primary Production in 1971 in Eagle Lake, California.**

	g C m^{-2} day^{-1}*	g C m^{-2} $year^{-1}$	Area (ha)	Metric Tons Carbon day^{-1}	Metric Tons Carbon $year^{-1}$
Limnetic phytoplankton	0.47	130	10,660	49.9	13,900
Littoral phytoplankton	0.34	102	281	0.96	287
Epilithic periphyton	0.33	100	1,150	3.8	1,150
Epiphytic periphyton					
on *Juncus balticus*	0.52	159	154	0.81	245
on *Scirpus acutus*	0.87	262	127	1.1	332
Macrophytes					
Juncus balticus	0.58	132	154	0.89	203
Scirpus acutus	1.42	324	127	1.80	412

* Average for the study period.

carbon m^{-2} day^{-1} (0.07 g carbon ft^{-2} day^{-1}) in mid-June to 0.069 g carbon m^{-2} (0.006 g carbon ft^{-2} day^{-1}) in mid-July. The summer average was 0.34 g carbon m^{-2} day^{-1} (0.03 g carbon ft^{-2} day^{-1} (Table 2).

Mean production by epilithic periphyton was 0.33 ± 0.11 g C m^{-2} day^{-1} (0.03 ± 0.01 g C ft^{-2} day^{-1}) ($P = 0.05$), based on macrophyte surface area. This was multiplied by macrophyte surface area per m^2 of lake surface area. *Juncus balticus* = 3.76 m^2 (40.5 ft^2); *Scirpus acatus* = 6.20 m^2 (66.7 ft^2). *Juncus* occupied a greater portion of the littoral area (Table 2), but the tremendous size of *Scirpus* resulted in its greater annual periphyton production. Annual production was calculated assuming productivity under the ice to be 17.4% of summer values as found by Pieczyńska and Szczepańska (1966). The icebound period was 77 days.

The mean macrophyte organic weight was 91.1 ± 2.1% ($P = 0.05$) of oven dry weight. There was no statistically significant difference between *Juncus* and *Scirpus* in terms of percent organic weight. Primary production values were calculated based on a growing season of 229 days (1 March–15 October), from the ice-free period until the shoots were killed by frost.

Since underground parts of macrophytes were not included in biomass determinations, estimates of annual production are probably low. As Wetzel (1964*b*) has indicated, the annual increment of growth of perennial macrophyte rootstocks is very difficult to determine. Hejny's data for *Scirpus lacustris* (Vollenweider 1969) indicates that the underground increment is about 70% of the green shoot increment. If the data are assumed to be true for *Scirpus acutus,* our estimates represent only 60% of its annual production. However, in terms of total primary production, the contribution by macrophytes would still be very small.

Other investigators have demonstrated the importance of littoral primary production in small lakes (Table 3). Lawrence Lake, Michigan — 4.96 ha (12.25 acres) — has an extensive littoral zone (Wetzel 1966, Allen 1971). Borax Lake, California, is shallow with a heavy growth of benthic algae (Wetzel 1964*a*). In Eagle Lake the majority of primary production is by phytoplankton. However, if the three basins are considered as separate lakes, the role of periphyton in the shallow north and central basins—mean depth = 3.9 m and 3.4 m (12.8 and 11.2 ft), respectively is quite significant, responsible for about one-fourth of total production. Thus, in large deep lakes, typified by Eagle Lake's south basin, phytoplankton production may be representative of total primary production, but in shallow lakes such as the north and central basins and Borax Lake, or in small lakes with a well developed littoral zone, contributions by periphyton and macrophytes cannot be ignored.

TABLE 3. **Contributions by Primary Producers to Annual Production in Selected Waters.**

Lake	Percent of Annual Production			
	Phytoplankton	Periphyton	Macrophytes	Reference
Lawrence Lake, Michigan	25.4	23.3	51.3	Allen 1971, Wetzel 1966
Borax Lake, California	24	69	7	Westlake 1966
Eagle Lake, California	86	10.5	3.5	Present study
North basin	67	30	3	
Central basin	70.5	24	5.5	
South basin	88.7	10.6	0.7	

ACKNOWLEDGEMENTS

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OCCURRENCE OF NATIVE FISHES IN ALAMEDA AND COYOTE CREEKS, CALIFORNIA[1]

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The recent occurrence of native fishes in two San Francisco Bay tributaries is compared with that of earlier periods as revealed by collection records. Alameda Creek, despite intensive urban development, has retained a major portion of its native fish fauna. In contrast, lower Coyote Creek, under similar conditions has apparently lost over half of the fish species originally present.

INTRODUCTION

The impact of civilization on California's biota is most apparent in the terrestrial flora and fauna. Less well known is the effect of environmental alteration and degradation on the aquatic biota. In particular, the welfare of native fishes has been of growing concern in recent years because of the interest generated by a large number of scientists, administrators, and laymen (Deacon and Bunnell 1970; Miller 1972; Moyle and Nichols 1974; and Pister 1974). With some 9 endemic genera and 25 endemic species among the nearly 70 recognized native species, the importance of preserving native fishes in California takes on added significance. However, since the early surveys of ichthyologists such as Girard, Jordan, and Snyder (among others), there have been no published reports of recent surveys of native freshwater fishes that could be used to determine their status under today's radically altered environmental conditions.

In response to this need, the California Department of Fish and Game began a survey in 1973 of native freshwater fishes of the State. Among the waters surveyed that year were two streams tributary to San Francisco Bay, Alameda and Coyote creeks. These streams were surveyed because of the availability of previous collection records and because of the historical role of Coyote Creek in the dispersion of native fishes from the Sacramento-San Joaquin River system to the coastal Pajaro (and Salinas) River system (Snyder 1913).

Snyder (1905) was the first to catalog the fishes present in Alameda and Coyote creeks. He identified 6 native species from the former and 13 from the latter. Hubbs (1925) discussed 2 of the 11 native species that he had

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collected from Coyote Creek in 1922. Seale (1934) collected eight native species from Alameda Creek.

During 1945, Donald A. Simpson (a collector for Steinhart Aquarium, California Academy of Sciences) collected freshwater fishes throughout northern and central California during a joint project with the California Division of Fish and Game. As a part of this project, on 19 May and 23–25 August, Simpson sampled eight stations in Coyote Creek, obtaining 780 specimens of six native species.

From 1927 to 1972, Follett has made periodic collections from both streams. However, these data have not been reported in the literature heretofore.

This report presents the results of these collections, all other collections from Alameda and Coyote creeks at the California Academy of Sciences (by Hopkirk, 1961; Merkel, 1953; and Shapovalov, 1938), as well as collections made on 20–21 June 1973 as part of the California Native Fishes Survey of the Department of Fish and Game (DFG, 1973), and compares the recent occurrence of native fishes with that of earlier periods.

STUDY AREA

Alameda Creek, Alameda County, and Coyote Creek, Santa Clara County, lie in a basin between the Diablo and Santa Cruz mountains of the Coast Ranges. Both streams arise in the Diablo Mountains and empty into south San Francisco Bay. Historically, Coyote Creek played a significant role in the migration of fishes from the Sacramento-San Joaquin River system to the coastal Pajaro (and Salinas) River system, which empties into Monterey Bay (Snyder 1913). Ayres (1862) and Snyder (1905) believed that periodic high discharges of fresh water into San Pablo and San Francisco bays allowed fish of the Sacramento-San Joaquin system to colonize the streams flowing into San Francisco Bay. Fossil evidence suggests, however, that colonization occurred in Middle or Late Pleistocene at lower sea levels than have occurred in the Recent (Casteel and Hutchinson 1973). The subsequent transfer of fish from Coyote Creek or its precursors was apparently a simple matter of headwater stream capture by the Pajaro River (Snyder 1913). The presence of similar fish faunas has led to the classification of these waters in the Sacramento Freshwater Fish Province (Hopkirk 1974).

Alameda Creek

Alameda Creek flows from the Diablo Mountains through the Sunol Valley and Niles Canyon into southeastern San Francisco Bay (Figure 1). Above its confluence with Calaveras Creek it is a narrow, intermittent stream. Below this point it is wider and permanent and has a greater flow, due primarily to water releases from Calaveras Reservoir.

Above Niles Canyon, Alameda Creek is relatively undisturbed and bordered primarily by oaks (*Quercus*) and grasses. The substrate is gravel with a scattering of boulders. From Niles Canyon to its mouth, the creek is severely channelized and the original floodplain marshland has been replaced by dense urban development. The substrate is still primarily gravel, but changes to sand and mud in the extreme lower reaches.

Historically, Alameda Creek was not permanently connected to San Francisco Bay (Snyder 1905). Instead, its waters flowed into the marshes of the San Francisco Bay floodplain and percolated into the soil. Only during seasonal periods of high water flow did it discharge directly into the Bay.

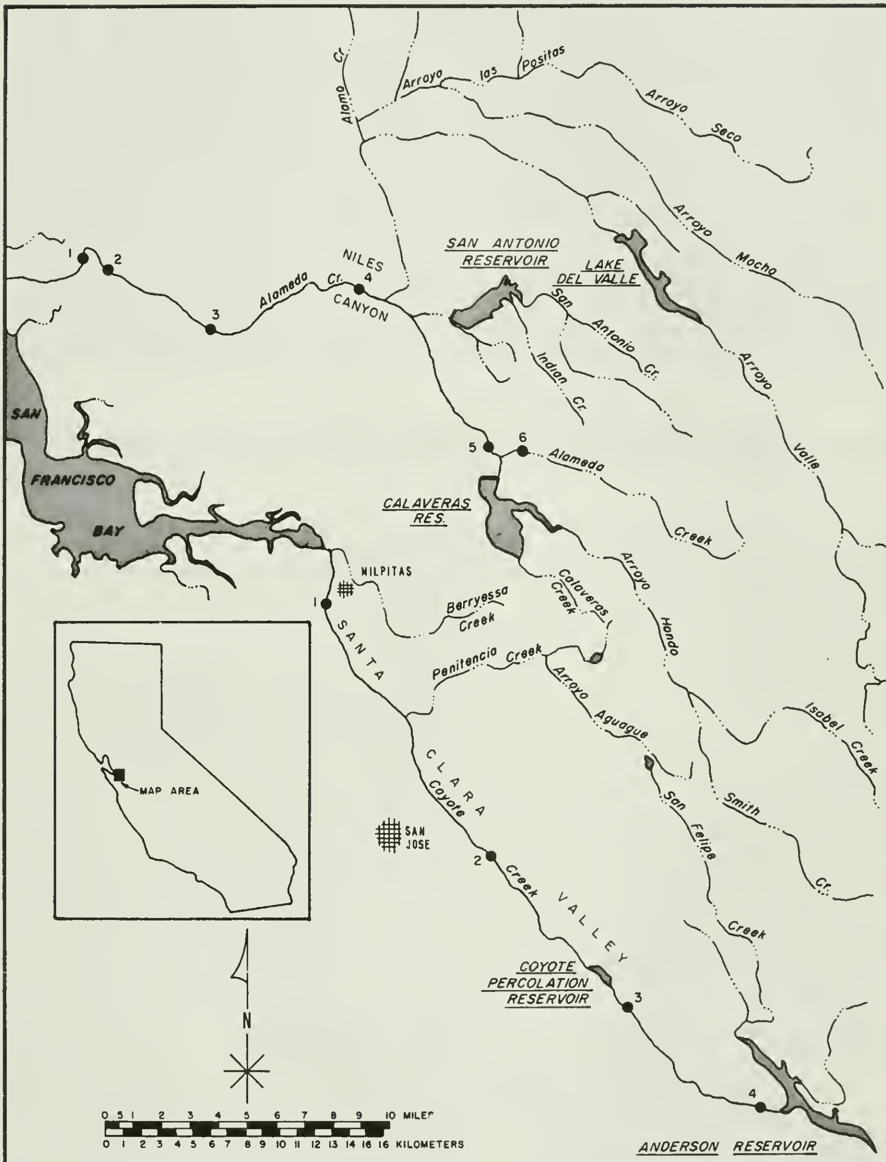

FIGURE 1. Location of 1973 collection stations on Alameda and Coyote creeks.

Coyote Creek

Coyote Creek also drains the Diablo Mountains and flows through the long Santa Clara Valley, emptying at the extreme southernmost point of San Francisco Bay (Figure 1). Three impoundments are on this creek: Coyote, Anderson, and Coyote Percolation reservoirs. Our 1973 collections

were confined to the section below Anderson Reservoir, some 48 km (30 miles) above the mouth. Coyote Reservoir is only 4 km (2.5 miles) above Anderson Reservoir. Above Coyote Reservoir the stream is intermittent.

The upper part of Coyote Creek below Anderson Reservoir is bordered primarily by oak woodlands. The substrate here consists of gravel and boulders. The lower part is surrounded by dense agricultural and urban development, the substrate ranging from gravel to mud. The amount of litter and debris within the stream was notably greater in the lower reaches.

A diversion dam seasonally placed just above the Milpitas sewage treatment plant approximately 1.6 km (1 mile) above the mouth effectively blocks upstream migration of anadromous species. Collections were not made below this point, since effluent was being dumped into the stream from the sewage treatment plant. This discharge appeared to preclude the presence of fish below, and probably presented a formidable barrier to fish movement.

TABLE 1. **Common and Scientific Names of the Fishes Known From Alameda and Coyote Creeks.**

Native Species	
Lampreys (Petromyzontidae)	
Pacific lamprey	*Entosphenus tridentatus* (Gairdner)
Western brook lamprey	*Lampetra richardsoni* Vladykov and Follett
Trouts (Salmonidae)	
Rainbow trout	*Salmo gairdneri* Richardson
Minnows (Cyprinidae)	
Thicktail chub	*Gila crassicauda* (Baird and Girard)
California roach	*Hesperoleucus symmetricus* (Baird and Girard)
Hitch	*Lavinia exilicauda* Baird and Girard
Sacramento blackfish	*Orthodon microlepidotus* (Ayres)
Splittail	*Pogonichthys macrolepidotus* (Ayres)
Sacramento squawfish	*Ptychocheilus grandis* (Ayres)
Speckled dace	*Rhinichthys osculus* (Girard)
Suckers (Catostomidae)	
Sacramento sucker	*Catostomus occidentalis* Ayres
Sticklebacks (Gasterosteidae)	
Threespine stickleback	*Gasterosteus aculeatus* Linnaeus
Sunfishes (Centrarchidae)	
Sacramento perch	*Archoplites interruptus* (Girard)
Surfperches (Embiotocidae)	
Tule perch	*Hysterocarpus traski* Gibbons
Sculpins (Cottidae)	
Prickly sculpin	*Cottus asper* Richardson
Riffle sculpin	*Cottus gulosus* (Girard)
Nonnative Species	
Minnows (Cyprinidae)	
Carp	*Cyprinus carpio* Linnaeus
Goldfish	*Carassius auratus* (Linnaeus)
Freshwater catfishes (Ictaluridae)	
White catfish	*Ictalurus catus* (Linnaeus)
Brown bullhead	*Ictalurus nebulosus* (Lesueur)
Livebearers (Poeciliidae)	
Mosquitofish	*Gambusia affinis* (Baird and Girard)
Sunfishes (Centrarchidae)	
Green sunfish	*Lepomis cyanellus* Rafinesque
Bluegill	*Lepomis macrochirus* Rafinesque
Largemouth bass	*Micropterus salmoides* (Lacépède)
Black crappie	*Pomoxis nigromaculatus* (Lesueur)

METHODS

Sampling was conducted by a variety of methods. From 1927 through 1972, seines, dip nets, and hook-and-line were the primary methods. In 1973, six locations on Alameda Creek and four locations on Coyote Creek were sampled with a Smith-Root Type V backpack electrofisher and with dip nets (Figure 1). Each sampling location encompassed a 50–100 m (164–328 ft) length of stream. The pH, D.O., and alkalinity were measured with a Hach Kit. An Industrial Instruments Model RA-2A conductivity meter was used to measure conductivity from which total dissolved solids (TDS) was estimated.

Specimens of fishes collected in 1973 are in the Department of Fish and Game Ichthyological Museum in Sacramento; those collected by Hubbs in 1922 are in the Museum of Zoology, University of Michigan, Ann Arbor; all others are in the California Academy of Sciences.

RESULTS AND DISCUSSION

The fishes represented in the collections and records cited are referable to 25 species, 22 genera, and 10 families (Table 1).

TABLE 2. **Number of Each Species of Fish Collected From Alameda Creek, Alameda County, 20–21 June 1973.** Size Range (FL mm) in Parentheses.

Species	Station				
	1	2	3	4	5
Native Species					
Pacific lamprey			1 (605)		
Hitch			8 (120–235)	1 (104)	
Sacramento blackfish			10 (41–322)		
Sacramento squawfish			2 (252–397)		
Sacramento sucker			14 (56–348)	5 (26–50)	6 (232–281)
Threespine stickleback	1 (63)	1 (61)			
Sacramento perch			19 (71–199)		
Prickly sculpin			10 (34–100)	2 (80–90)	
Nonnative Species					
Carp	24 (21–216)			1 (204)	
Goldfish			3 (142–184)		
Mosquitofish		14 (20–46)			
Green sunfish			20 (72–113)		

Alameda Creek

Eight native and four nonnative species were collected in Alameda Creek in 1973 (Table 2). The Sacramento sucker occurred at three of six stations, and hitch, threespine stickleback, prickly sculpin, and carp each were collected at two stations. No fish were collected at Station 6, a section characterized by low dissolved oxygen (Table 3). This station was above that portion of Alameda Creek affected by discharge from Calaveras Reservoir.

Snyder (1905) found only six native species in Alameda Creek: California roach, hitch, Sacramento squawfish, Sacramento sucker, tule perch, and prickly sculpin. Subsequent collections, however, indicate that at least five and probably six additional species were native to Alameda Creek (Table 4). Rainbow trout (probably an anadromous population) were collected by Follett in 1927 and Sacramento blackfish and threespine stickleback were collected by Seale in 1934.

Riffle sculpin were collected in Alameda Creek at the junction with Calaveras Creek by Leo Shapovalov of the California Division of Fish and Game in 1938. (The record of this species by Seale (1934) is based on a misidentification of the prickly sculpin, as shown by his statement, "The anal has 18 rays," rather than 13, 14, or 15.) Although Pacific lamprey were not collected in Alameda Creek until 1955, it is probable that this widespread anadromous species was originally present but was overlooked in the early collections. Four native and four nonnative species were collected in Alameda Creek between Niles and Sunol by John D. Hopkirk of the University of California, Berkeley, in 1961.

Sacramento perch may not have occurred in Alameda Creek within historic time. None were collected there prior to 1953. Their occurrence at that time generally has been considered to be the result of an introduction into Calaveras Reservoir some time after its construction in 1925. Although there is no known record of their presumed introduction, they were not collected in the reservoir until 1943, at about the time the California Department of Fish and Game began a planting program for Sacramento perch (Aceituno and Nicola in 1976).

Thus it appears that at least 11 (including Pacific lamprey) and possibly 12 (if the Sacramento perch is included) species were native to Alameda Creek rather than the 6 recorded by Snyder. Only the California roach, tule perch, and riffle sculpin now appear to be absent, although tule perch may persist in isolated gravel-pit ponds in the lower drainage (W. Strohschein, Calif. Dept. Fish and Game, pers. commun.). Although steelhead were not collected in 1973, they have run up the stream in recent years (W. Strohschein, pers. commun.), after apparently having disappeared sometime in the late 1950's. Further studies are needed, however, to determine whether the species is permanently reestablished as part of the native fauna. Although California roach and riffle sculpin appears to be gone from Alameda Creek, they may still persist in intermittent headwater tributaries, since they are known to prefer cooler temperatures.

It is significant to note that no nonnative species were collected from Alameda Creek at least through 1934, even though most of those subsequently encountered had been introduced into California well before the turn of the century. The appearance of nonnative species coincides roughly with the disappearance of California roach, tule perch, and riffle sculpin, although a causal effect is not suggested. It was also at this time that rapid development and urbanization of the floodplain was occurring.

TABLE 3. **Environmental Variables at 6 Collection Localities on Alameda Creek, Alameda County, 20–21 June 1973.**

Variable	Station 1	2*	3	4	5	6
Elevation (m)	0	0	12	55	134	207
Latitude	37°33′	37°34′	37°34′	37°35′	37°30′	37°30′
Longitude	122°04′	122°03′	121°59′	121°55′	121°49′	121°47′
Date	6-20-73	6-20-73	6-20-73	6-20-73	6-20-73	6-21-73
Time	1100	--	1600	1930	1800	0630
Water temp. (C)	26	--	18	23	14	19
Secchi disk trans. (cm)	56	--	77	100	77	50
pH	8.5	--	8.5	8.4	7.9	7.1
D.O. (ppm)	9.8	--	--	8.6	--	2.8
Conductivity (microhms)	425	--	325	295	200	360
TDS (ppm)	308	--	282	230	194	292
Alkalinity						
phenolphthalein (ppm)	20.5	--	0	6.8	0	0
methyl orange (ppm)	138.8	--	130.0	109.4	109.4	198.4

* Water quality data not obtained.

TABLE 4. **The Occurrence of Fishes in Various Collections From Alameda Creek, Alameda County, 1905–1973.**

Species	Year and Collector										
	1905 Snyder	1927 Follett	1934 Scale	1938 Shapovalov	1953 Follett	1955 Follett	1957 Follett	1958 Follett	1961 Hopkirk	1972 Follett	1973 DFG
Native Species											
Pacific lamprey						X	X				X
Rainbow trout		X				X	X				?
California roach	X		X				X		X		
Hitch	X		X			X				X	X
Sacramento blackfish			X			X	X	X	X	X	X
Sacramento squawfish	X	X	X		X		X		X	X	X
Sacramento sucker	X	X	X				X		X	X	X
Threespine stickleback			X								X
Sacramento perch					X	X	X	X		X	X
Tule perch	X	X	X								
Prickly sculpin	X	X	X			X	X				X
Riffle sculpin				X							
Nonnative Species											
Carp						X	X	X		X	X
Goldfish											X
White catfish						X					
Brown bullhead								X	X		
Mosquitofish									X		X
Green sunfish									X		X
Bluegill					X	X	X	X			
Largemouth bass					X				X		
Black crappie								X			

Coyote Creek

Eight species of fish were collected in 1973 in lower Coyote Creek, six native and two nonnative (Table 5). Hitch were distributed most widely, being found in three of four collection stations. Sacramento sucker, threespine stickleback, and prickly sculpin each were collected at two stations. Each of the remaining species was collected only once.

TABLE 5. **Number of Each Species of Fish Collected From Coyote Creek, Santa Clara County, 21 June 1973.** Size Range (FL mm) in Parentheses.

Species	Station 1	Station 2	Station 3	Station 4
Native Species				
Rainbow trout				1 (201)
Hitch		3 (67–83)	5 (67–181)	2 (124–142)
Sacramento blackfish			8 (32–223)	
Sacramento sucker			3 (293–330)	3 (78–318)
Threespine stickleback	3 (28–31)		8 (21–44)	
Prickly sculpin			17 (31–119)	4 (114–138)
Nonnative Species				
Goldfish	12 (18–165)			
Mosquitofish	7 (16–19)			

The upper two stations on Coyote Creek were found to be significantly different from the lower two both in water quality and in number and kinds of fish. Both total dissolved solids (TDS) and total alkalinity greatly increased in the lower two stations of the stream, having a mean of 530.5 ppm and 270.2 ppm, respectively, compared with a mean of 272.0 ppm and 157.3 ppm for the upper two stations (Table 6). The greatest divergence in these parameters occurred between Stations 2 and 3 with a difference of 201 ppm TDS and 89 ppm in total alkalinity. These differences are more than double those of any other adjacent stations. Near San Jose (Station 2), the stream becomes a very slow, almost stagnant pool. These conditions probably explain the greater abundance of fish at the upper two stations.

Snyder (1905) found 13 species of native fishes in Coyote Creek, including several that escaped his attention in Alameda Creek. However, he apparently overlooked the Sacramento perch, found there in 1922 by Hubbs and in 1932 by Follett. In addition, Hubbs (1925) recorded numerous specimens of a nonparasitic lamprey in Coyote Creek in 1922 which Follett regards as the western brook lamprey. Vladykov (1973) believed

TABLE 6. **Environmental Variables at Four Collection Localities on Coyote Creek, Santa Clara County, 21 June 1973.**

Variable	Station 1	Station 2	Station 3	Station 4
Elevation (m)	5	30	58	116
Latitude	37°25′	37°19′	37°13′	37°10′
Longitude	121°55′	121°51′	121°45′	121°38′
Time	1640	1400	1130	1015
Water temp. (C)	28	23	17	12
Secchi disk trans. (cm)	38	33	102	77
pH	8.3	7.6	8.0	7.7
D.O. (ppm)	10.0	7.0	12.8	10.6
Conductivity	795	660	345	240
TDS (ppm)	552	509	308	236
Alkalinity				
phenolphthalein	0	0	0	0
methyl orange	280.4	260.0	171.0	143.6

them to represent an undescribed species. Although riffle sculpin were not collected until 1953 by Terrence J. Merkel, University of California, Berkeley, it is probable that they had always been present but not encountered by earlier collectors. Thus we conclude that at least 16 species were native to Coyote Creek around the turn of the century.

Of the six native species that we collected in 1973, all were also found by Snyder (1905). Seven species were recorded by Snyder but were not found by us: Pacific lamprey, California roach, thicktail chub, splittail, Sacramento squawfish, speckled dace, and tule perch. Adult Pacific lamprey were observed in 1964, but not in later years; they were at a low dam (at an elevation of about 58 m) east of the Santa Teresa Hills, about 4 km (2.5 miles) downstream from Coyote Percolation Reservoir (John Swickard, Five Dot Ranch, pers. commun.). Prickly sculpin were collected by Follett near this low dam in 1964.

Thicktail chub, splittail, and speckled dace have not been reported since Snyder's original visit; western brook lamprey and tule perch seem to have disappeared sometime after 1922, and Sacramento perch after 1932. The records by Follett for California roach, Sacramento squawfish, and Sacramento sucker in 1964 and for California roach in 1972 are from the vicinity of Gilroy Hot Springs, some 22 stream km (14 miles) above Anderson Dam, but those in 1944 are from southwest of Milpitas, near our Station 1. The record for riffle sculpin in 1953 by Merkel is from Penitencia Creek (tributary to Coyote Creek) at the lower boundary of Alum Rock Park. It appears that although California roach and Sacramento squawfish are now absent from the stream below Anderson Reservoir, they, and possibly riffle sculpin, may still persist in the upstream waters. Therefore, we tentatively conclude that of the 16 native species originally occurring in lower Coyote Creek, at least 9 are now absent.

Although only goldfish and mosquitofish were collected in 1973, at least three other nonnative species (carp, bluegill, and largemouth bass) may be present in Coyote Creek (Table 7).

TABLE 7. The Occurrence of Fishes in Various Collections From Coyote Creek, Santa Clara County, 1905–1973.

Species	Year and Collector									
	1905 Snyder	1922 Hubbs	1932 Follett	1941 Follett	1944 Follett	1945 Simpson	1953 Merkel	1964 Follett	1972 Follett	1973 (DFG)
Native Species										
Pacific lamprey	X	X	X	X						
Western brook lamprey		X								
Rainbow trout	X					X				X
Thicktail chub	X									
California roach	X	X		X	X	X		X	X	
Hitch	X									X
Sacramento blackfish	X	X	X			X				X
Splittail	X									
Sacramento squawfish	X	X			X	X		X		
Speckled dace	X									
Sacramento sucker	X	X			X	X		X		X
Threespine stickleback	X	X	X	X	X	X			X	X
Sacramento perch		X	X							
Tule perch	X	X								
Prickly sculpin	X	X	X					X		X
Riffle sculpin		X					X			
Nonnative Species										
Carp					X					
Goldfish										X
Mosquitofish				X						X
Bluegill								X		
Largemouth bass								X		

CONCLUSIONS

Despite the effects of extreme urbanization in its lower portion, Alameda Creek appears to retain a substantial part of its presumed native fish fauna (at least 9 of 12 species). If we accept the premise that Pacific lamprey, Sacramento blackfish, threespine stickleback, and riffle sculpin were probably present originally but were overlooked by Snyder, then only the California roach, tule perch, and riffle sculpin appear to be lost from the native fauna.

On the other hand, Coyote Creek (below Anderson Reservoir) apparently has lost over half of its native fish fauna (9 of 16 species). Conditions for the remaining native species could be improved by providing a sufficient discharge from upstream reservoirs to eliminate the stagnant water conditions in the lower section and to dilute the effluent from the Milpitas sewage treatment plant.

All species of fish currently lacking from both Alameda and lower Coyote creeks, with the exception of the endangered and possibly extinct thicktail chub, are available elsewhere in the State for restocking. Were habitat conditions to improve, some species would probably return naturally.

ACKNOWLEDGMENTS

We would like to acknowledge the assistance of Allen Cuenca of the Alameda County Water District during the collecting on Alameda Creek in 1973, and Al Gasgon of the Santa Clara County Water and Flood Control District during the collecting on Coyote Creek in 1973. We thank John Swickard of the Five Dot Ranch for information regarding lampreys in Coyote Creek, and Lillian J. Dempster of the California Academy of Sciences for assistance with the manuscript.

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OBSERVATIONS OF COMMON MERGANSER BROODS IN NORTHWESTERN CALIFORNIA[1]

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Observations of common merganser, *Mergus merganser*, broods were made on six floating surveys and three roadside surveys of the Klamath and Trinity rivers of northwestern California in summer 1973. Ten aged broods were estimated hatched between 23 May and 26 June 1973. Average brood size for 52 broods was 8.2 chicks (range 1 to 24). Broods were spaced an average of 5.6 km (3.5 miles). Chick mortality was estimated at 20 to 50%. Broods were found generally in the water and near the shore. Of 52 broods, five were attended by no adult, 40 by one adult, one by two adults and six by three to six adults.

INTRODUCTION

Perhaps owing to its disfavor as a game species, the common merganser (*Mergus merganser*) has received little attention from the scientific community. Most of the interest has been stimulated by a fear of depredations on game fisheries. Hence, the bulk of the literature has dealt with the food habits. This, together with the ever-present controversy over the utilization of the river resources of northwestern California, led to an investigation of the general behavior and status of the common merganser in northwestern California.

STUDY AREA

The study area included 91.7 km (57 miles) of the Klamath River and 40.2 km (25 miles) of the Trinity River in Humboldt and Del Norte counties in northwestern California (Figure 1). It is a region of high ridges and deep canyons. The lower Klamath River cuts through a narrow coastal belt of forest dominated by coast redwood (*Sequoia sempervirens*). The Trinity and upper Klamath study sections are in a forested region dominated by Douglas fir (*Pseudotsuga menziesii*) with Pacific madrone (*Arbutus menziesii*), red alder (*Alnus rubra*), tanoak (*Lithocarpus densiflorus*), Oregon white oak (*Quercus garryana*) and California black oak (*Q. kelloggii*) along the river courses. The watersheds are used mainly for timber production and livestock grazing.

Annual precipitation in the study area ranges from about 76 cm (30 inches) along the Trinity River to 203 cm (80 inches) along the lower Klamath River. Most of the precipitation falls as rain between October and March. Summer high temperatures in the interior portions of the study area average about 35 C (95 F) while high temperatures near the mouth of the Klamath average about 21 C (70 F).

Because the Klamath and Trinity rivers have major reservoirs on their headwaters, their flows in the dry season, when broods are present, are relatively stable. This flow is greatly reduced from the winter and spring.

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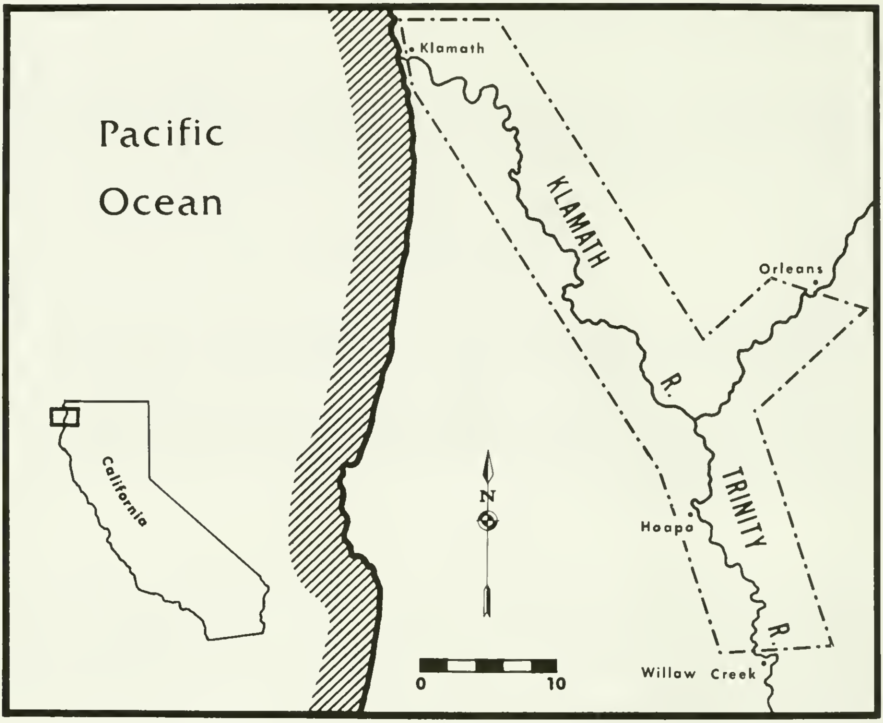

FIGURE 1. Klamath and Trinity rivers of northwestern California showing study area selected.

METHODS

Data were collected on six floating surveys from 26 June to 14 August 1973. The surveys took 1 to 3 days each and totaled 9 days. The surveys ranged from 21.9 km to 109.9 km (13.6 to 68.3 miles) and totaled over 288 km (179 miles). The surveys were made in a six-man rubber raft with an assistant who helped control the raft and locate broods. Additional brood observations were made from the road on 30 May, 31 May and 9 June along the upper Klamath River. (No broods were seen on three roadside surveys of 19–21 May.) Four roadside surveys of the Klamath River estuary were conducted from 28 May to 8 August.

Data gathered on each brood included the location (midstream, near shore, on shore), shore type (vegetated bank, cliff, rocky beach, sandy beach), brood activity (feeding, loafing, moving, escaping), number of chicks and age of brood. The age was determined using the aging criteria of Erskine (1971).

RESULTS AND DISCUSSION

Dates of Hatching

Of 10 broods which were carefully aged, seven were estimated at 2–7 days old and three were estimated at 7–15 days old (Figure 2). The 10 broods probably hatched between 23 May and 26 June. However, an examination of the chick numbers recorded on the six surveys (Table 1) indicates that either not all eggs were hatched or not all young were on the main river until mid-July.

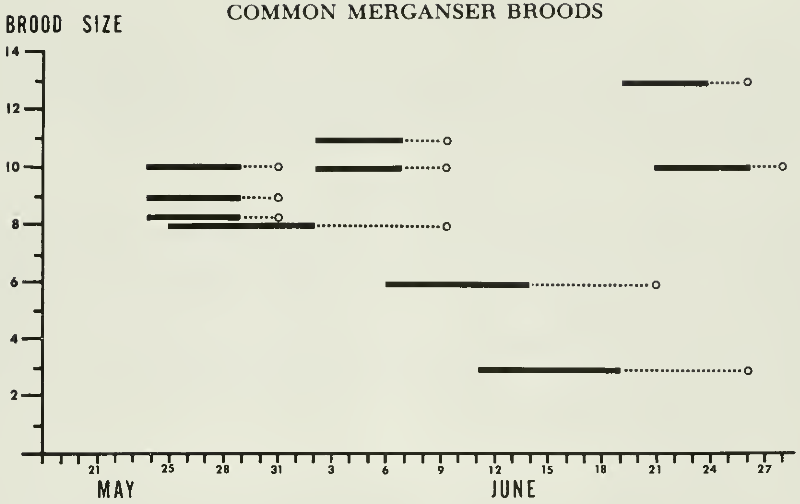

FIGURE 2. Date of observation (circle), estimated hatching date (solid bar) and size of 10 common merganser broods observed in summer 1973 in northwestern California.

Most of the brood reports in the literature are not adequate for estimating the date of hatching. Erskine (1971) listed 1 June as the earliest and 25 July as the latest dates of hatching in 3 years of study in eastern Canada. Dawson (1923) reported a brood in California estimated at less than a week old on 24 June. Gabrielson and Lincoln (1959) reported downy young in Alaska from late June to early August. Yocom (1951) saw a brood of six young about 2 weeks old on the Snake River in Washington as early as 16 May.

TABLE 1. **Common Merganser Brood Size and Spacing Data on Six Surveys of the Klamath and Trinity Rivers, Northwestern California, in Summer 1973.**

Date	Miles	No. chicks	No. broods	Ave. brood size	Miles per brood	Chicks per mile
26–27 June	44.5	81	13	6.2	3.4	1.8
2 July	19.2	50	4	12.5	4.8	2.6
19–21 July	68.3	206	22	9.4	3.1	3.0
31 July	13.6	26	4	6.5	3.4	1.9
7 Aug.	18.0	38	6	6.3	3.0	2.1
14 Aug.	15.6	24	3	8.0	5.2	1.5
Overall	179.2	425	52	8.2	3.5	2.4

Brood Size and Spacing

Stutz (1965) reported an average brood size of 11.4 chicks (range 4 to 26) for 16 common merganser broods in Oregon. Others have reported miscellaneous broods ranging mostly from 6 to 12. Combined broods of up to 40 chicks have been reported by Roberts (1936), Munro and Clemens (1937), White (1957), Stutz (1965) and Erskine (1971).

The average brood size of 52 broods observed throughout the season was 8.2 chicks (SD = 5.7) (Table 1). Brood spacing averaged about 4.6 km (3.5

miles). The range in brood size was 1 to 24 chicks with a median of seven chicks (Figure 3). The large disjoint brood sizes of 18 (n = 3), 19 (n = 2), 20 (n = 1) and 24 (n = 1) were likely combined broods. No broods were seen on any of the four surveys of the Klamath River estuary.

Chick Mortality

Sixteen broods which had originally totaled 131 chicks were relocated 17 to 22 days later, when they totaled 105 chicks. This indicates a loss of 20%. The estimated ages of the broods at the time of the original sighting ranged from 1 to 3 weeks.

An examination of the 10 aged broods (Figure 2) reveals that seven broods in the first week of life averaged 10.0 chicks whereas three broods in the second week of life averaged 6.3 chicks. This indicates a loss of 37% in the first 2 weeks of life.

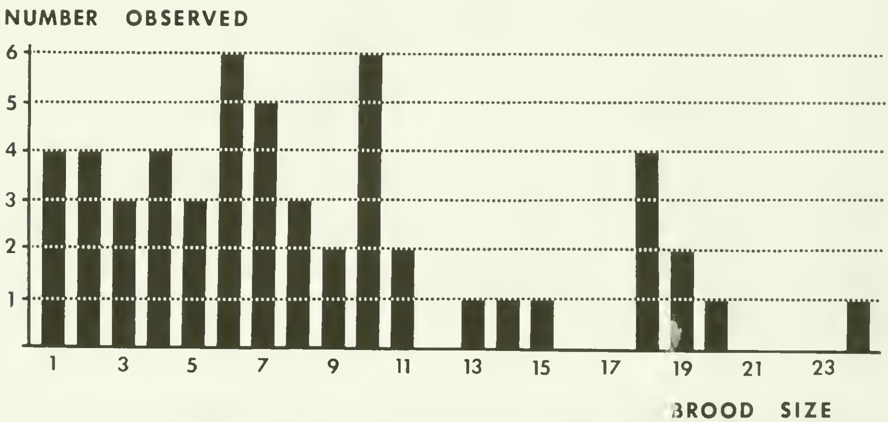

FIGURE 3. Frequency distribution of brood size for 52 common merganser broods observed on six surveys of Klamath and Trinity rivers of northwestern California in summer 1973.

Data concerning the mortality of chicks within broods is difficult to analyze due to the combining and switching of broods (White 1957). An examination of the chick numbers (Table 1) obtained on the six surveys reveals a peak in mid-July when all broods are evidently present on the main river. Surveys conducted after this date show a steady decline in chicks to about 50% of the peak.

Brood Habitat

Broods were found generally in the water near the shore (Table 2). They were seen in midstream when moving from one shore to the other or when fleeing from danger. The occasional brood seen along a cliff shore was usually moving from one section of the river to another. No broods were seen in the estuarine area during the study period. The abundance of potential predators, such as gulls, and the wide, deep river flow are believed significant. Other important factors in the estuarine area were the heavy power boat usage, the lack of shoreline vegetation, and wave action along the shore.

Young chicks appeared to prefer to feed in the shallow water along the river's edge where the shoreline consisted of beaches of rocks 2.5 to 25.4 cm (1 to 10 inches) in diameter. The water velocity in such areas was slow as the protruding rocks or shallowness of the water impeded the river's

TABLE 2. **Location and Activity of 52 Broods Seen on Six Surveys of the Klamath and Trinity Rivers, Northwestern California, in Summer 1973.**

Activity	Midstream		Near shore		On shore	
	No.	%	No.	%	No.	%
Feeding			13	25		
Loafing	2*	4			7	13
Moving	3	6	4	8		
Escaping	11	21	12	23		
Total	16	31	29	56	7	13

* Midstream logs.

flow. The primary feeding method for chicks was probing for food items while swimming on the surface with the head submerged. As they fed, the chicks normally moved along the shore with the lagging chicks periodically scurrying to the front.

Only 17% of the broods were seen out of the water (Table 2). The only habitats in which I saw broods leave the water to loaf were sand and gravel beaches (13%) and midstream logs slanting upward out of the water (4%). Such loafing sites afforded good visibility up and down the river. One brood in its first week of life was observed continuously from 0900 to 1500 hours. The brood left the water only once at 1300 hours for 33 min. The chicks spent the time out of the water sleeping with their heads tucked under their wings.

Four times I saw broods which had previously fled downstream reappear from vegetation hanging over the water. In all four instances, the broods sought cover only after disappearing around a bend in the river. As far as I know, none of the four broods actually left the water to hide.

Parental Care

White (1957) pointed out that common merganser chicks can rear themselves without parental care. Of the 52 broods seen, five were not attended by an adult. One downy brood of 18 chicks had two adults with it. Six broods of nearly adult size were seen in the company of three to six adult birds. The remaining 40 broods were each attended by one adult.

Young broods invariably left and returned to the water with their mother. A mother who attempted to roost on a midstream boulder usually was forced from her position by the clamouring of the young as they fought for positions under or near her.

When moving from one area to another and not feeding, young chicks followed their mother closely often with two or three chicks riding on her back; there was a continual turnover of riders as the jumping chicks displaced their broodmates. Broods which became dispersed during feeding were regularly collected by the mother's soft quacking.

As a brood was approached by the drifting raft, the chicks usually moved cautiously along the shore with the mother leading and sometimes quacking softly. If disturbed, the brood ran over the water in a tight bunch with the mother usually following. Only one brood of two chicks attempted escape by diving; the pair was not accompanied by an adult.

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AGE AND LENGTH COMPOSITION OF NORTHERN ANCHOVIES, *ENGRAULIS MORDAX*, IN THE CALIFORNIA ANCHOVY REDUCTION FISHERY, 1973–74 SEASON

by

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A record total of 109,394 megagrams (120,587 short tons) was landed in the California reduction fishery during the 1973–74 season. Age composition of the catch was dominated by age-group II (1971 year-class) although age-group III (1970 year-class) contributed a significant amount to southern California landings. Catch composition from central California was comprised mainly of age-groups I, II and III (1972, 1971 and 1970 year-classes).

INTRODUCTION

This is the seventh in a series of reports on age, length, and sex composition of anchovies caught for reduction in California. Data were derived from samples collected between September 15, 1973, and April 30, 1974, in southern California and August 1, 1973, through May 15, 1974, in central California. Methods of sampling and age determination were those used by Collins (1971). Total landings were a record 109,394 megagrams (120,587 short tons) of which 80% was landed at San Pedro, 16% at Port Hueneme, and 4% at Moss Landing (Table 1).

TABLE 1. **Anchovy Landings by Port During 1973–74 Season.**

Port	Mega grams	Percent of total
Southern California		
San Pedro	87,836	80.3
Port Hueneme	17,591	16.0
Central California		
Moss Landing	3,967	3.7
Total	109,394 (120,587 short tons)	100.0

Estimated numbers by length, year class, weight, and sex were calculated from samples taken at San Pedro and Moss Landing. A total of 540 samples consisting of 7,353 individual fish was processed from San Pedro and 103 samples and 928 fish from Moss Landing.

THE FISHERY

A record price of $57.50 per short ton was paid to the fishermen at the beginning of the season, but the price fell to $41.25 per short ton by the end of the season.

The southern California fleet was comprised of 38 boats with an estimated total capacity of 3500 megagrams (3860 short tons) per day. Limits of 23 to 50 megagrams (25 to 55 short tons) per boat were frequently imposed. Fishing effort was intense during the fall, and by the end of February, the 90,718 megagrams (100,000 short tons) quota had been met for the first time since the fishery began. The season closed on March 1 but was reopened on March 8 by the California Fish and Game Commission with the quota increased by 18,144 megagrams (20,000 short tons). Two restrictions were imposed. No fishing was to take place within 12 miles of the mainland shore and the season would close on April 30. These regulations applied only to the 1973–74 season.

The fleet in the northern zone consisted of 13 lampara boats and 2 purse seiners with a catch capacity of approximately 218 megagrams (240 short tons) per day. Two reduction plants were capable of processing 200 megagrams (220 short tons) per day. Fishing in this area was most successful during the fall and spring when good weather prevailed.

LENGTH COMPOSITION OF THE CATCH

Southern California

Anchovies landed at San Pedro ranged from 66 to 162 mm (2.6 to 6.4 inches) standard length (SL). Mean length of the total sampled catch was 119 mm (4.7 inches) SL, while mean length for a 5,000 ton sample stratum varied from 129 mm (5.0 inches) SL in November to 109 mm (4.3 inches) SL in January.

Fish between 105 and 124 mm (4.1 and 4.9 inches) SL comprised 61% of the estimated 4.5 billion fish landed at San Pedro, which was similar to the 1972–73 season when 70% of the fish were in that size range (Table 2). The percentage of fish geater than 125 mm (4.9 inches) SL was 29.5%, as compared to 17% for the 1972–73 season (Sunada 1975). The increased number of larger fish can be attributed to greater numbers of age group III (1970 year class) fish. Length at age data indicate little change from the 1972–73 season (Figure 1). Females were slightly larger than males for most year classes (Figure 2).

TABLE 2. **Estimated Number of Anchovies by Length Group Landed at San Pedro During 1973–74 Season.**

Length group (mm SL)	Estimated number	Standard deviation	Percent of landings
75–84	7,122,400	2,911,686	0.15
85–94	64,425,670	13,647,895	1.43
95–104	339,883,212	28,024,431	7.55
105–114	1,236,506,334	43,262,304	27.46
115–124	1,515,707,984	39,178,669	33.67
125–134	917,011,192	27,490,028	20.37
135–144	357,402,977	17,718,094	7.93
145–154	58,815,137	7,571,248	1.30
155–164	4,692,794	1,892,719	0.10
Total	4,501,567,700		99.96

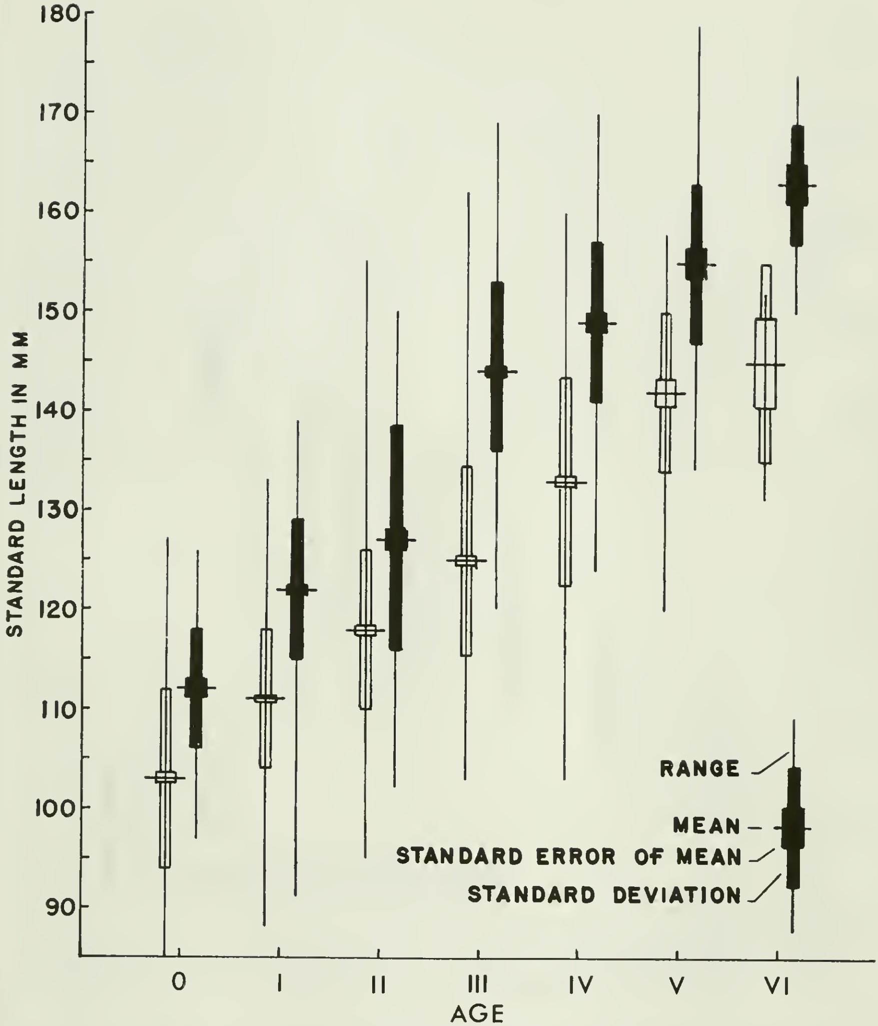

FIGURE 1. Length at age of northern anchovies for the 1973–74 fishing season. Open figures—San Pedro, closed figures—Moss Landing.

Central California

Central California fish ranged from 91 to 179 mm (3.6 to 7.0 inches) SL. Fish above 135 mm (5.3 inches) SL comprised 55% of the estimated 126 million anchovies landed (Table 3). This was considerably smaller than was observed during the 1972–73 season when 85% of the fish were larger than 135 mm (5.3 inches) SL (Sunada 1975). Small fish appeared early in the season and remained available through spring. Mean lengths at age for

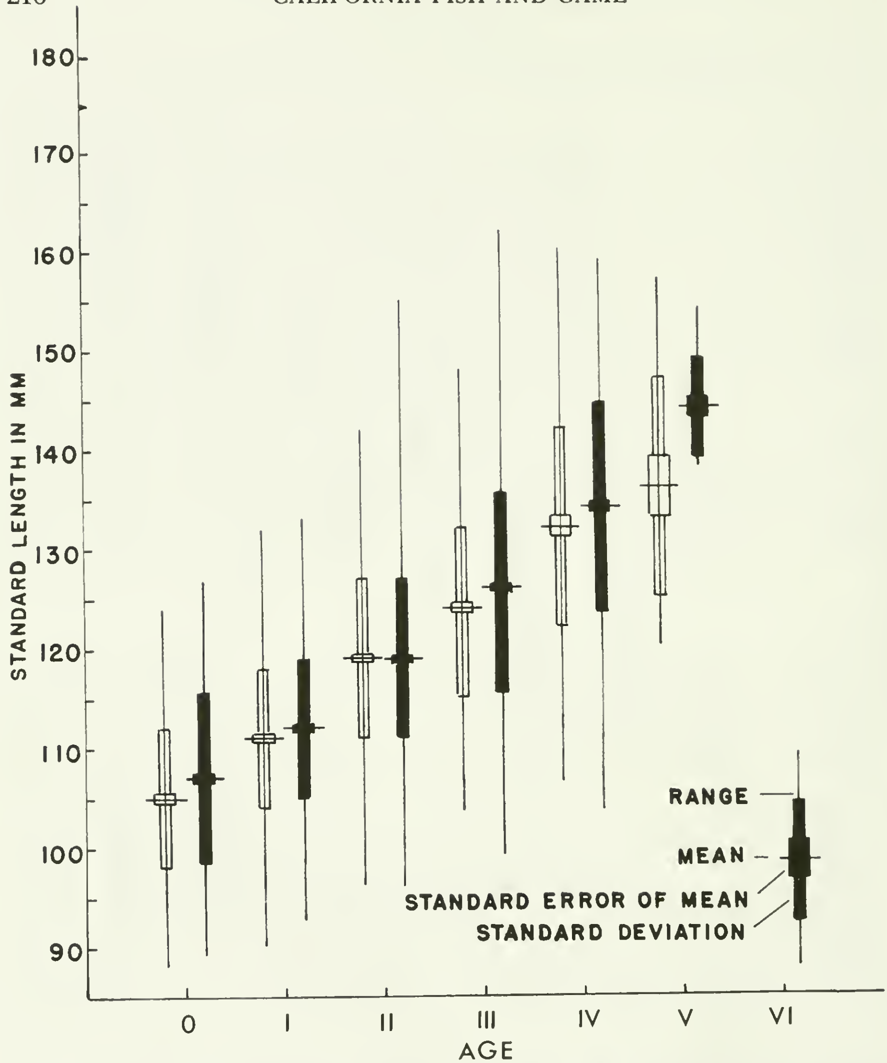

FIGURE 2. Length at age of males (open figures) and females (closed figures) for the 1973–74 season, San Pedro samples.

most ages were smaller than during the 1972–73 season. Although the mean lengths at age were smaller, they still were 10 mm (0.4 inch) larger than fish landed at San Pedro (Figure 1). This discrepancy cannot be explained on a genetic basis since research has shown the population off central and southern California to be homogenous. However, these results were similar to findings by Collins (1969), Spratt (1972), and Sunada (1975). Females were larger than males in older age groups (Figure 3).

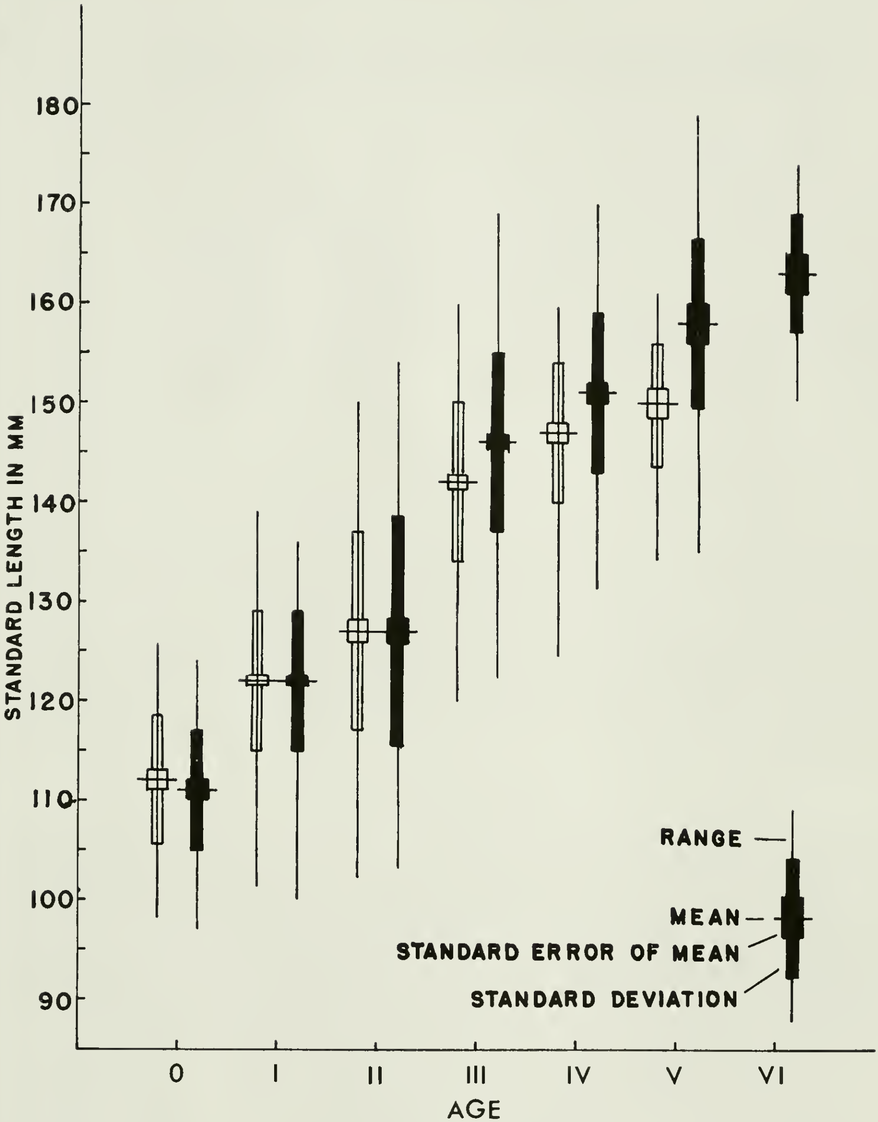

FIGURE 3. Length at age of males (open figures) and females (closed figures) in the 1973–74 season; Moss Landing.

AGE COMPOSITION OF THE CATCH

Otoliths were used for determining age, and year classes were assigned according to methods devised by Collins and Spratt (1969).

Southern California

The catch composition was predominantly age groups I, II, and III (1972, 1971, and 1970 year classes), 86% by number and by weight (Table 4). This was similar to the 1972–73 season when those age groups totaled 88% by number and 86% by weight (Sunada 1975).

TABLE 3. **Estimated Numbers by Length of Anchovies Landed at Moss Landing for Reduction in Northern Permit Area During 1973–74 Season.**

Length group (mm SL)	Estimated number	Standard deviation	Percent of landings
85–94	55,543	128,253	0.04
95–104	1,329,803	1,799,665	1.05
105–114	9,360,898	5,322,047	7.40
115–124	20,522,150	6,761,682	16.23
125–134	25,065,090	9,352,470	19.82
135–144	25,569,982	4,586,477	20.22
145–154	26,901,873	5,740,370	21.27
155–164	14,308,278	4,495,425	11.31
165–174	3,261,685	3,211,585	2.57
175–184	54,098	65,471	0.04
Total	126,429,400	---	99.95

The 1970 year class, the dominant year class for the 1971–72 and 1972–73 seasons, was again conspicuous this season as age group III (Spratt 1973; Sunada 1975) (Figure 4). This age group contributed 35% by weight and 31% by number, although the dominant age group by number was age group II (1971 year class) which comprised 35% of the catch (Table 4). Age group I (1972 year class) fish appeared in similar numbers as compared to previous seasons. The occurrence of age group 0 and I fish increased and dominated the catch during the winter and spring months (Figure 5).

Central California

Compared to previous seasons, central California catches consisted of smaller and younger fish. Age groups I, II, and III (1972, 1971, and 1970 year classes) comprised 68% of the landings by weight and 73% by number (Table 5), in comparison to last season, when the catch was dominated by age groups II, III, and IV (Sunada 1975). Age group I (1972 year class) was present in considerable numbers throughout the year, and it appears that the anchovies were fully recruited at this age. Age group 0 (1973 year class) made its appearance during winter and spring (Figure 6).

SEX AND WEIGHT RATIO

Southern California

A female to male numerical ratio was 2.01 : 1 and a weight ratio of 2.18 : 1 (Table 6). The two ratios were similar to those of the 1972–73 season, 1.98 : 1 by number and 2.14 : 1 by weight (Sunada 1975). The substantial numbers of the 1970 year class (age group III), with a high proportion of females, was definitely a factor in this ratio (Figure 7). The ratio of females to males of the fishery remained fairly constant throughout the season, although it approached 1 : 1 during January and February when the younger age groups were recruited into the fishery.

TABLE 4. Estimated Weight and Number of Anchovies by Year Class and Age Landed at San Pedro for Reduction in Southern California During 1973–74 Season.

	Year class (age)							
	1973 (0)	1972 (I)	1971 (II)	1970 (III)	1969 (IV)	1968 (V)	1967 (VI)	Total
Kilograms	3,786,957	13,483,455	28,663,072	29,223,912	7,015,404	741,514	76,188	82,990,505
Standard deviation	298,918	467,483	683,609	719,840	425,580	141,162	54,949	
Percent	4.56	16.24	34.53	35.21	8.45	0.89	0.09	99.97
Number	312,037,083	908,487,474	1,588,473,368	1,388,069,844	276,967,435	25,103,592	2,428,904	4,501,567,700
Standard deviation	25,918,180	31,652,602	38,169,910	32,061,845	16,699,507	4,739,295	1,715,157	
Percent	6.93	20.18	35.28	30.83	6.15	0.55	0.05	99.97

TABLE 5. Estimated Weight and Number of Anchovies by Year Class and Age Landed at Moss Landing for Reduction in Northern California During 1973–74 Season.

	Year class (age)							
	1973 (0)	1972 (I)	1971 (II)	1970 (III)	1969 (IV)	1968 (V)	1967 (VI)	Total
Kilograms	98,485	744,597	487,921	1,430,970	736,597	315,796	95,914	3,910,280
Standard deviation (kilo)	60,475	286,548	124,333	268,542	197,298	105,557	47,107	
Percent	2.51	19.0	12.47	36.59	18.83	8.07	2.45	99.96
Numbers	6,234,877	32,793,339	19,601,984	39,963,159	18,500,846	7,417,432	1,917,763	126,429,400
Standard deviation	3,951,667	11,554,071	5,413,076	7,047,749	4,664,463	2,385,001	934,463	
Percent	4.93	25.93	15.50	31.60	14.63	5.86	1.51	99.96

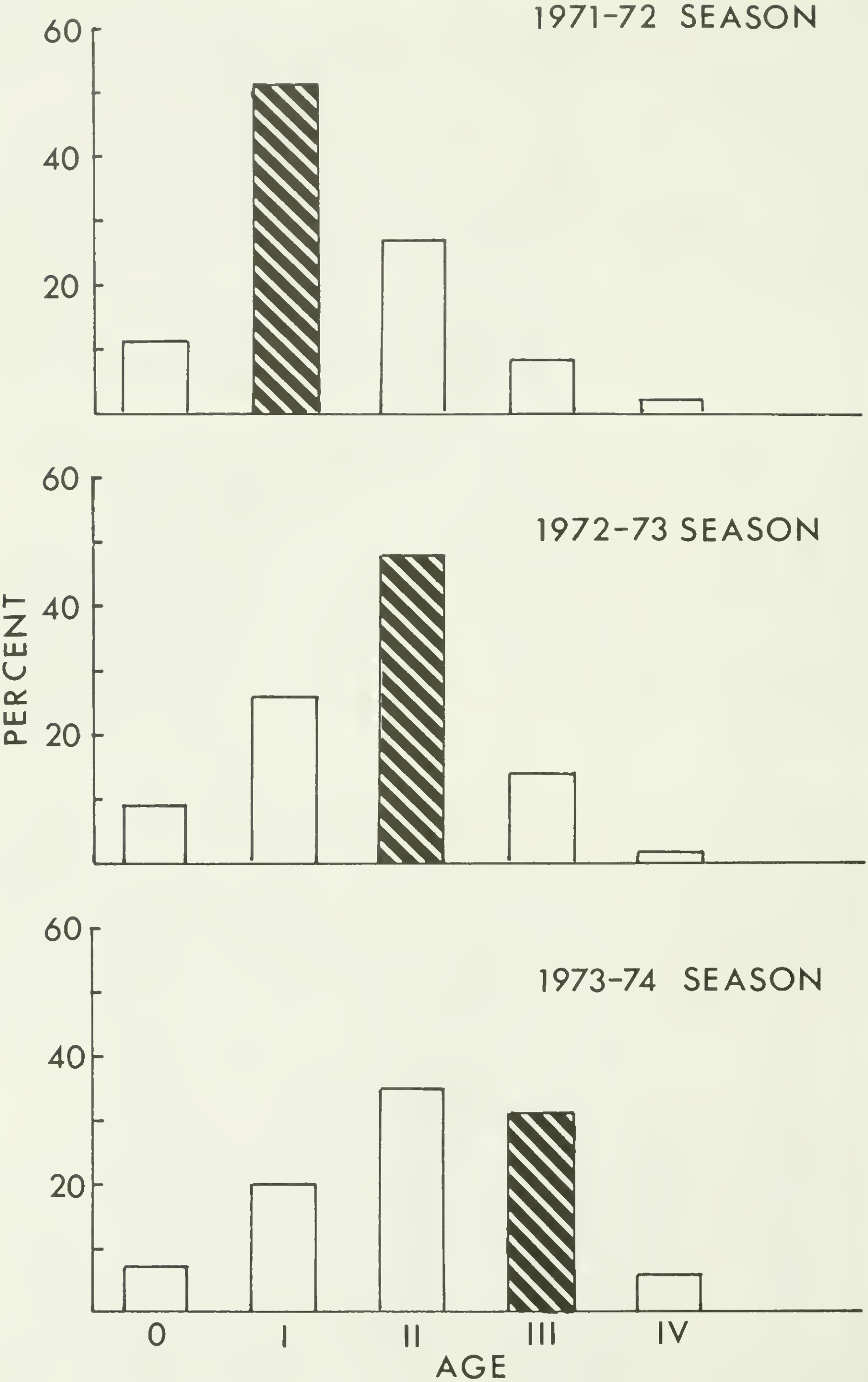

FIGURE 4. Estimated percent composition by numbers of anchovies landed at San Pedro (barred figures —1970 year class).

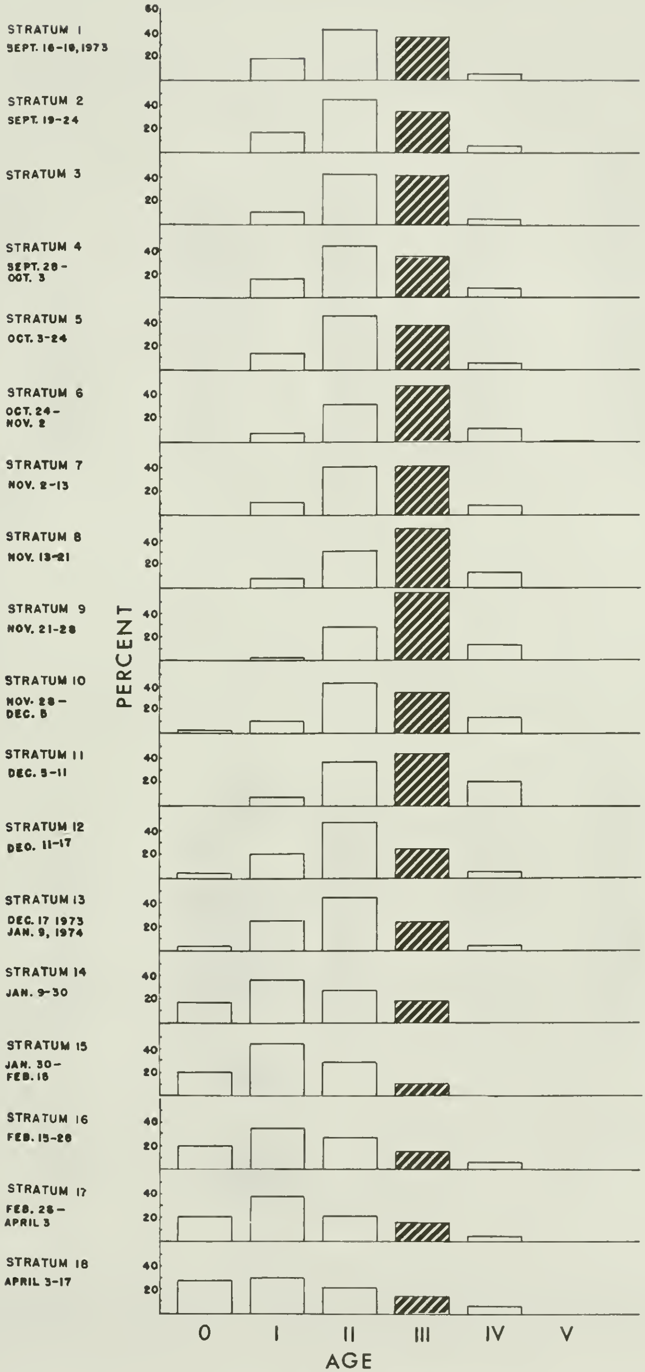

FIGURE 5. Percent frequency occurrence of age groups per 5000 ton stratum. San Pedro landings (barred figures—1970 year class).

TABLE 6. **Sex Ratio by Number and Weight of Anchovy Landings for 1973–74 Season.**

Sex ratio	San Pedro	Moss Landing
Males		
Number	1,347,519,316.	59,313,000.
Percent	29.9	46.9
Females		
Number	2,720,631,561.	66,761,066.
Percent	60.4	52.8
Unknown		
Number	433,416,823.	355,334.
Percent	9.6	0.2
Females : males	2.01 : 1	1.12 : 1
Weight ratio (in kg)		
Males		
Weight	24,069,902.	1,708,842.
Percent	29.0	43.7
Females		
Weight	52,554,068.	2,195,080.
Percent	63.32	56.1
Unknown		
Weight	6,366,534.	6,358.
Percent	7.67	0.1
Females : males	2.18 : 1	1.28 : 1

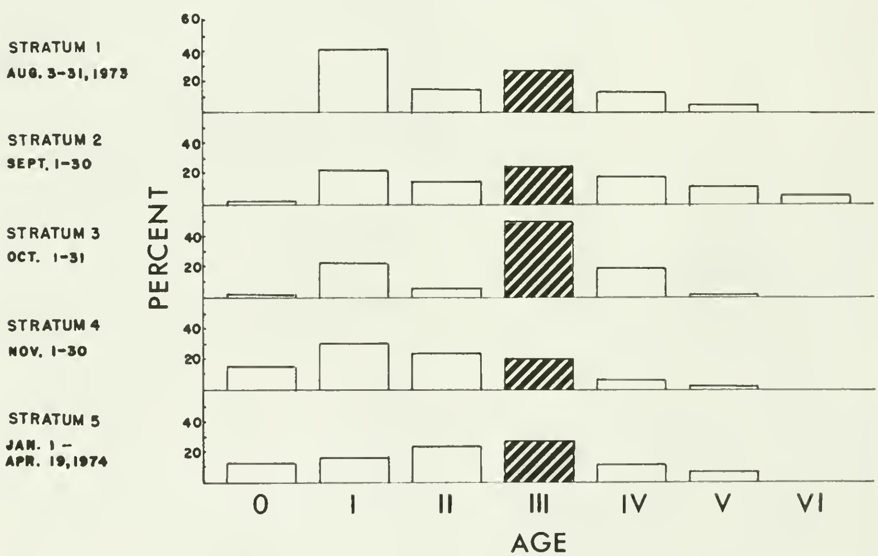

FIGURE 6. Percent frequency occurrence of age groups per stratum. Moss Landing landings (barred figures—1970 year class).

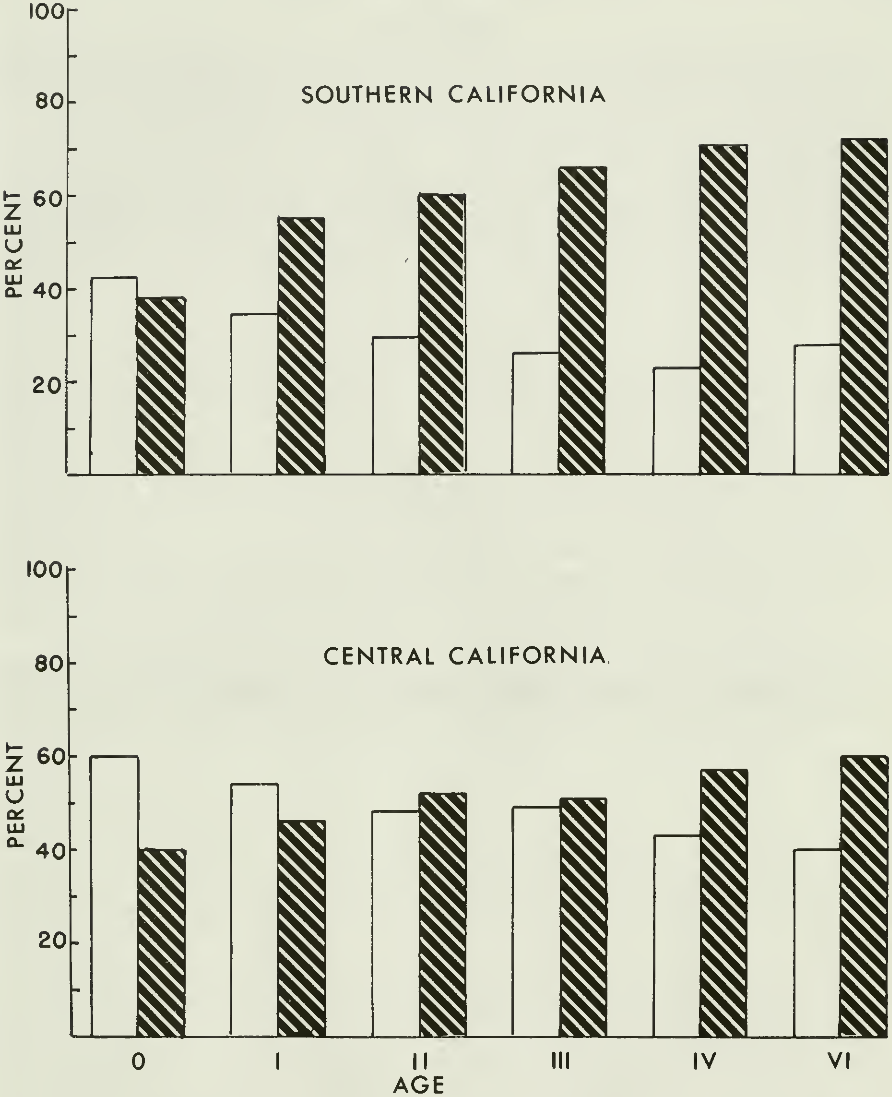

FIGURE 7. Percentage of northern anchovy males and females by age group from the 1973–74 season (males—open figures) female (barred figures).

Central California

Female to male ratios of anchovies from central California were 1.12 : 1 by number and 1.28 : 1 by weight (Table 6). This was a considerable decrease from the previous season when the numerical ratio was 2.05 : 1 (Sunada 1975). The reduced ratio reflects the influence of fish from age groups I and II, where males are equal in proportion to females (Figure 7).

CONCLUSION

Southern California landings were the largest in history, and fishing appears not to have adversely affected the anchovy population. The 1970 year class was exceedingly strong during the 1972–73 season and was again strong during the 1973–74 season.

Central California data revealed an influx of smaller and younger fish which was a change from the previous season. The 1973–74 season's catch was the largest in several years and as in southern California, the indications are that the anchovy population is in no danger of being overexploited.

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NOTES

FALL AND WINTER FOODS OF AMERICAN COOTS ALONG THE LOWER COLORADO RIVER

This paper presents an analysis of the food items of 250 coots collected during the fall and winter 1970–71 and 1971–72 along the lower Colorado River. Although the coot is a common-to-abundant winter resident in this area (Eley 1975), no data have been available on their food habits.

Jones (1940) reported that the diet of 792 coots from throughout the United States was composed of 89.39% plant foods and 10.61% animal foods. Thompson (1973) examined 31 coots from the Mississippi River in Iowa and found that birds collected in backwaters consumed chiefly aquatic plants while those collected in open water consumed more animal foods. Other data on coot food habits were reported incidentally by Wetmore (1920), Bent (1926), Harris (1954), Ryder (1961) and Burger (1973).

One hundred two coots were collected between October 1970 and January 1971 and 148 coots were collected between October 1971 and January 1972. The birds were collected, by shooting, along a 40.2 km (25 mile) stretch of the Colorado River extending from Imperial Dam (Imperial County, California and Yuma County, Arizona) on the north to Morelos Dam (Yuma County, Arizona and Sonora, Mexico) on the south.

The combined contents of the esophagus, proventriculus and gizzard of each bird were separated manually into individual items, unidentifiable items and grit, and air dried. The volume of food items and grit was measured by water displacement to the nearest 0.1 cc and contents measuring less than 0.05 cc were recorded as traces. Unidentifiable items were classified as plant material, animal material or unidentifiable organic material. Grit was tabulated separately. Plant nomenclature follows Kearney and Peebles (1969).

Along the lower Colorado River coots are aquatic herbivores. Plant material constituted 97.4% of the food volume and was recovered from all 250 birds (Table 1). Sago pondweed was the most important food item recovered. No significant sex or age selectivity for specific food items was detected.

Most plant food consisted of green leaves and stems. A few seeds of cattail, sago pondweed, and tamarix were recovered; and California bulrush (*Scirpus californicus*), screwbean mesquite (*Prosopis pubescens*), sege (*Carex* sp.) and rush (*Juncus* sp.) were represented entirely by seeds.

The leaves of three species of trees were found in the coots: Fremont cottonwood (*Populus Fremontii*), Goodding's willow (*Salix Gooddingii*) and tamarix. All these species of trees border the river and their leaves and the beans of screwbean mesquite commonly were seen floating near shore.

Animal foods, comprising only 1.1% of the total food volume, were relatively unimportant in this sample of coots. Dragon flies (Odonata) were the most abundant animal food followed by flies (Diptera) and freshwater shrimp (*Palaemonetes paludosus*).

Grit was present in all gizzards. Cloth (0.2 cc), apparently part of a sock, was found in one gizzard, and feathers, apparently from coots, were found in two gizzards.

TABLE 1. **Foods Found in 250 American Coots Collected Between October, 1970 and January, 1972 Along the Lower Colorado River.**

Item	Frequency of Occurrence	Percent of Frequency	Volume (cc)	Percent of Food Volume
PLANT FOODS				
Algae				
Pithophora sp.	76	30.4	240.3	22.2
Angiospermae				
Typha latifolia	51	20.4	109.3	10.1
Potamogeton pectinatus	116	46.4	305.4	28.3
Potamogeton sp.	6	2.4	9.4	0.9
Najas marina	8	3.2	22.5	2.1
Distichlis stricta	36	14.4	62.2	5.8
Phragmites communis	35	14.0	79.8	7.4
Scirpus californicus	9	3.6	15.9	1.5
Eleocharis macrostachya	14	5.6	23.2	2.1
Carex sp.	8	3.2	3.5	0.3
Juncus sp.	1	0.4	2.1	0.2
Populus Fremontii	3	1.2	0.4	trace
Salix Gooddingii	3	1.2	1.4	0.1
Prosopis pubescens	2	0.8	0.6	trace
Tamarix pentandra	48	19.3	28.0	2.6
Unidentified Plant Material	176	70.4	147.7	13.7
Total Plant Foods	250	100.0	1051.6	97.4
ANIMAL FOODS				
Pelecypoda				
Cibicula leana	1	0.4	0.2	trace
Crustacea				
Palaemonetes paludosus	3	1.2	1.8	0.2
Unidentified crustacean	1	0.4	0.4	trace
Insecta				
Siphlonurus sp.	3	1.2	0.7	trace
Order Odonata	10	4.0	6.4	0.6
Order Diptera, Family Muscidae	4	1.6	1.1	0.1
Unidentified insect	1	0.4	0.3	trace
Osteichthyes				
Fish bones	2	0.8	0.9	trace
Unidentified Animal Material	4	1.6	1.3	0.1
Total Animal Foods	25	10.0	13.1	1.1
UNIDENTIFIED ORGANIC MATERIAL	25	10.0	16.2	1.5
TOTAL FOODS	250	100.0	1080.9	100.0

Coots were observed leaving the water to eat bread, apple cores, orange peels, marshmallows, watermelon rinds, popcorn, and fish bait left by fishermen, picnickers, campers and hunters. At the base of Imperial Dam coots took handouts, usually bread, from fishermen and campers.

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